SCIENTIFIC AGRICULTURE

Vol. XX JUNE, 1940 No. 10

FURTHER STUDIES ON *RHAGOLETIS POMONELLA* (WALSH)[1]

A. D. PICKETT[2] AND M. E. NEARY[3]

Dominion Entomological Laboratory, Annapolis Royal, N.S., Department of Agriculture, Truro, N.S.

[Received for publication April 5, 1940]

INTRODUCTION

The senior author (6) has previously published morphological and biological studies on the apple maggot, *Rhagoletis pomonella* (Walsh), and closely related forms, designed to establish the relationships of the representatives of the genus *Rhagoletis* Loew which develop in the fruits of apple, hawthorn, blueberry and snowberry (*Symphoricarpus racemosus* Michx.). The conclusion was reached that only one species, *Rhagoletis pomonella* (Walsh), was concerned, and that the slight morphological differences observed in the various stages of the insect from different hosts were associated largely with size. It was also shown that adult females could be induced to deposit eggs in the fruits of host plants other than those in which they were reared as larvae, and that apparently normal larvae developed from these eggs and subsequently pupated.

The results of this previous breeding work with flies from apple, hawthorn, and blueberry may be summarized as follows:

1. Flies captured on apples deposited viable eggs in blueberries, giving rise to larvae and later to pupae; while flies reared or captured on apple behaved normally on hawthorn, depositing eggs from which larvae and pupae developed.

2. Reared hawthorn flies oviposited in apple, producing larvae which later developed into pupae.

3. Blueberry flies in one cage deposited eggs in apple, but, in general, these flies appeared to have difficulty in penetrating the skin of apples. Negative results were obtained on haws with blueberry flies which seemingly were unable to penetrate the skin of the fruit.

4. Eggs deposited in apples by apple females crossed with blueberry males developed normally, while the progeny of apple females and hawthorn males likewise developed in apple.

5. The observations made during the course of the studies did not indicate any major biological difference between the apple, hawthorn and blueberry forms of *R. pomonella* (Walsh), but did suggest that Hopkins' (4) "host selection principle" may satisfactorily explain those minor differences which apparently exist.

[1] Contribution from the Division of Entomology, Science Service, Dominion Department of Agriculture, Ottawa, Ontario, and the Division of Entomology, Nova Scotia Department of Agriculture, Truro, N.S.
[2] Officer-in-Charge.
[3] Assistant in Entomology.

CONTINUATION OF BIOLOGICAL STUDIES

The methods used in the investigations herein reported were similar to those followed in the previous studies (6), except that the feeding mixture for the flies was composed of 5% honey and 2 to 3% yeast, in equal parts of fresh milk and distilled water. In practically all cases the flies appeared to behave normally in the cages and lived a considerable length of time.

A recheck of the cages used in 1935 showed that 2 pupae had developed in hawthorn from 114 blueberry males and females. The small number of pupae compared to the number of adults is of interest. Previous observations had led us to believe that blueberry flies found difficulty in penetrating the skins of haws with their ovipositors, but the above result indicates that they may occasionally be successful.

Table 1 shows the results obtained in the breeding investigations in 1936. In Cage 1, flies reared on apple laid eggs in plum, and 37 mature larvae were collected. This confirms results obtained by Hall (3). It is interesting to note that flies reared on apple from a cross of blueberry males with apple females deposited fertile eggs in the apple from which 33 mature larvae were obtained. This definitely proves that the progeny from a cross of apple and blueberry forms are fertile. The progeny of a cross of hawthorn and apple flies also proved fertile as shown by the results in cage 9.

In cage 11, one pupa was obtained from 80 hawthorn flies confined on the snowberry, *Symphoricarpus racemosus* Michx.

Table 2 gives the results obtained in 1937. Cages 1 and 2 showed that apple and blueberry flies respectively deposited eggs in plum, and mature larvae were obtained in both cases. Cage 3 showed that the maggots of the apple form are capable of developing in the fruits of mountain ash, *Sorbus americanus* Marsh.

In cage 8, containing apple females and blueberry males, 44 mature larvae were obtained, thus confirming the results previously secured (6).

TABLE 1.—FRUIT FLY EXPERIMENTS, 1936

Cage No.	Females reared on:	Males reared on:	Host placed on:	No. of flies in cage	No. mature larvae collected
1	Apple	Apple	Abundance plum	112	37
2	Hawthorn	Hawthorn	Blueberry	25	0
3	Flies from apple males and females reared on hawthorn 1935		Hawthorn	25	0
4	Flies from a cross of apple females and blueberry males, reared on apple 1935		Apple	15	33
5	Hawthorn	Hawthorn	Abundance plum	150	0
6	Apple	Hawthorn	Apple	30	48
7	Hawthorn	Hawthorn	Pear	150	0
8	Apple	Apple	Pear	30	2
9	Flies from a cross of hawthorn females and apple males, reared on hawthorn 1935		Hawthorn	14	11
10	Blueberry	Blueberry	Abundance plum	20	0
11	Hawthorn	Hawthorn	Snowberry	80	1

TABLE 2.—FRUIT FLY EXPERIMENTS, 1937

Cage No.	Females reared on:	Males reared on:	Host placed on:	No. of flies in cage	No. mature larvae collected
1	Apple	Apple	Plum	60	27
2	Blueberry	Blueberry	Plum	26	14
3	Apple	Apple	Mountain Ash	50	9
4	Blueberry	Blueberry	Mountain Ash	14	0
5	Apple	Apple	Apple	150	60
6	Apple	Apple	Hawthorn	150	0
7	Blueberry	Apple	Apple	50	0
8	Apple	Blueberry	Apple	80	44
9	Blueberry	Blueberry	Hawthorn	35	0
10	Apple	Apple	Chokecherry	150	0
11	Apple	Apple	Snowberry	40	7
12	Hawthorn	Hawthorn	Snowberry	25	2

TABLE 3.—FRUIT FLY EXPERIMENTS, 1939

Cage No.	Females reared on:	Males reared on:	Host placed on:	No. flies in cage	No. mature larvae collected
1	Apple	Apple	Cherry (sweet)	40	9
2	Apple	Apple	Plum	40	45
3	Apple	Apple	Mountain Ash	75	0
4	Blueberry	Apple	Blueberry	25	0
5	Apple	Apple	Blueberry	150	2
6	Apple	Apple	*Daphne*	60	0
7	Apple	Apple	Hawthorn	90	19
8	Apple	Apple	Apple	80	30
9	Apple	Blueberry	Apple	20	9
10	Apple	Apple	Pear	22	0
11	Apple	Apple	Mountain Ash	150	0
12	Apple	Apple	Snowberry	24	0

Cage 12 contained hawthorn flies confined on snowberry from which 7 pupae were taken, thus confirming the results obtained in cage 11 in the 1936 experiments as shown in Table 1. Cage 11 contained apple flies from which 7 mature larvae were obtained from snowberry. These results would appear to confirm the relationship which the writers believe exists between the apple and snowberry forms.

In the 1938 work no results were obtained. The authors are at a loss to explain this since it was a year when these flies were very active under natural conditons. The extremely wet season may have had something to do with the failure of the flies to oviposit.

Table 3 gives a summary of the 1939 experiments. In cage 1, flies reared on apple deposited eggs in sweet cherry, and 9 mature larvae were subsequently recovered. Hall (3) reports breeding the apple form on Montmorency cherry. In cage 2, 45 mature larvae, the progeny of apple flies, were reared on plum. In cage 9, apple females crossed with blueberry males oviposited on apple, and larvae developed to maturity.

DISCUSSION OF RESULTS AND CONCLUSIONS

It will be observed by reference to these data and to those previously published (6) that adults of *R. pomonella* which were reared in apple showed a considerable amount of adaptability in respect to hosts, producing offspring which developed to the mature larval stage in the following fruits: blueberry, hawthorn, pear, plum, mountain ash, snowberry and sweet cherry. In addition to the results obtained in our own studies, Hall (3) has added tomato, sour cherry and *Cornus amomum* Mill. Hall (3) states that eggs were deposited in cranberry (presumably *Vaccinium macrocarpon* Ait.). It is quite likely that the insect can develop in this fruit; the senior author has examined third instar larvae from cranberry which resembled very closely those developing in apple.

In our experiments flies reared on blueberry have been induced to deposit eggs, from which larvae developed, in apple, plum and hawthorn, when confined in cages on these fruits. In the case of the hawthorn only 2 mature larvae were recovered after many trials.

Hawthorn flies appear more reluctant about changing hosts than do either the apple or blueberry forms. Hawthorn flies will oviposit in apple quite readily and the larvae develop to maturity, and adults have been secured. The snowberry is the only fruit other than apple and hawthorn in which we have been able to induce these flies to oviposit. It is quite possible that the failure of the flies to oviposit in blueberry is due to their late emergence.

These results indicate that the flies reared on apple are more adaptable in their food habits than the others. This also appears to be borne out in Hall's (3) experiments. If the hypothesis set forth by Hall (3) and others is correct, i.e., that these flies all originated from a single species of *Rhagoletis*, then it is only reasonable to expect that the apple form would be fixed in its food habits to a lesser extent, since apples have been grown in America for a comparatively short time. All the other fruits regarded as natural hosts are native. With one possible exception we have never found larvae of these flies in the fruit of introduced species of hawthorn, although these are very common in some of the districts where heavily infested apples and native hawthorns are found.

TABLE 4.—RESULTS OF CROSSING EXPERIMENTS

Females	Males	No. of cages	Approx. No. flies used	No. pupae developed	Remarks
Apple	Blueberry	4	322	106	Pupae recovered from all cages. 2nd generation produced.
Blueberry	Apple	4	142	0	Copulation noted on one occasion. No oviposition observed.
Apple	Hawthorn	3	70	48	Results in one cage only.
Hawthorn	Apple	1	63	36	
Blueberry	Hawthorn	1	5	0	Blueberry flies usually dead when hawthorn flies appear.
Hawthorn	Blueberry	0			Not tried.

Table 4 shows the results obtained in attempts to induce the flies reared from apple, blueberry and hawthorn to cross-breed. It will be noted that apple females and blueberry males produced 106 mature larvae in 4 cages and that some results were obtained from all of them. In the reciprocal cross, i.e., with blueberry females and apple males, we have had only negative results. It might be observed, however, that the number of flies was considerably smaller, but this would not appear to be sufficient to account for the difference. On only one occasion was mating noted in these cages and there did not appear to be any attempts at oviposition. Since the male apple flies are considerably larger than the male blueberry flies there may be a physical obstacle to mating between these flies.

Considering the small number involved in crosses between apple and hawthorn flies and the number of mature larvae procured, there would appear to be no difficulty with this cross, although Hall's (3) results would suggest the converse.

When the small number of flies involved in attempts to cross the blueberry and hawthorn flies is considered, it is not surprising that negative results were obtained. The fact that the blueberry flies emerge considerably earlier than the hawthorn flies makes it difficult to obtain a sufficient number of both forms at the same time. Since the emergence of apple flies is intermediate to that of the blueberry and hawthorn forms there is no difficulty involved in making crosses with either.

From these studies the authors feel they have secured a reasonable amount of evidence that suggests a close relationship between the flies reared from the three host plants mentioned. There does not appear to be any sound basis for considering the blueberry form as a different species. These investigations suggest that host influences have a bearing on the seasonal development of these insects and that the appearance of adult flies is synchronized with the prime condition of the host for oviposition. This is further substantiated by the work of Hall (2 and 3) with the same species reared on different hosts, and also by the work of Wiesmann (8) with *R. cerasi* L. in Switzerland on cherry and *Lonicera*.

Whether the tendency of the female fly to select the kind of fruit in which she developed as a larva is due to an inherent character which has been established by a continuous adherence to one species of food plant is a debatable point. The "host selection principle" as set forth by Hopkins (4) would appear to support the theory, and the work of Craighead (1) and others would tend to lend strength to this hypothesis. Thorpe and Jones (7), however, could not find definite evidence to support this view in their work with the parasitic *Nemeritis canescens* (Grav.), although there was an indication of a tendency in this direction. It is quite evident that the female insect is attracted to its host in some specific manner. There is considerable evidence to indicate that olfactory responses are involved in some cases at least, but this does not satisfactorily explain the whole situation. It is quite apparent in some cases that, while the female insect is attracted to a specific host or may be confined to it, she may accept or reject any particular host individual as a suitable environment on or in which to deposit eggs. To the writers there would appear to be two phenomena involved in the selection of hosts. The first is concerned with the attraction of the reproductive form to the plant or other host, and the

second is concerned with the discretionary powers on the part of the individual insect as to whether the plant or other host is or is not a suitable environment for the deposition of eggs. In other words, a stimulus of some nature attracts the female to the host species, but some further stimulus is then necessary, or some specific set of conditions must exist, to induce the female to oviposit on any particular host individual.

Further, in regard to the second point, it would appear that the insect's choice of host may be influenced by more than one factor, and that both physical and chemical features may be involved. In the case of *Rhagoletis pomonella* (Walsh) it would appear from observation that chemical, physical, and ecological factors are concerned. The insect appears at or near the time at which the fruit is in a suitable condition for the deposition of eggs, and on coming out of the soil goes to a species of plant which is a suitable host. It is seldom that adults of *Rhagoletis pomonella* are found on other than its preferred hosts, except possibly for short periods. It would appear that the first attraction to the host is a response to olfactory stimuli. Finally the female is able in some way to differentiate between varieties of fruits. Whether this is due to a chemical or a physical response, or both, is not clear. Sweet fleshed apples are more liable to attack than are those more tart, but it also appears that the physical condition of the fruit is a factor since apparently more susceptible varieties of apples are thin skinned. Also, the authors noted numerous attempts or apparent attempts of blueberry flies to oviposit on haws; these were largely unsuccessful. Blueberry flies also appeared to have difficulty in penetrating the skin of apples. Painter (5) has suggested that the three factors mentioned above, namely, chemical, physical, and ecological may be concerned in the selection of food plants by insects. If it can be definitely established that these factors are involved in regard to the species under consideration, it would indicate that host selection may be explained on a physico-chemical basis, as contrasted to the somewhat complicated theory that it may be due to larval memory which is carried through to the adult stage.

ACKNOWLEDGMENTS

The authors wish to thank Mr. W. A. Ross, Chief, Fruit Insects Investigations, Division of Entomology, Science Service, Dominion Department of Agriculture, Mr. J. A. Hall, Dominion Entomological Laboratory, Simcoe, Ontario, and Dr. J. McB. Cameron, Provincial Entomologist for Nova Scotia, for assistance and advice in preparing the manuscript.

REFERENCES

1. Craighead, F. C. Hopkins' host-selection principle as related to certain Cerambycid beetles. Journ. Agr. Res. 22 : 189-220. 1921.
2. Hall, J. Allan. Observations on the biology of the apple maggot. 67th Annual Rept. Ent. Soc. Ont. pp. 46-53. 1936.
3. Hall, J. Allan. Further observations on the biology of the apple maggot *Rhagoletis pomonella* (Walsh). 69th Annual Rept. Ent. Soc. Ont. pp. 53-58. 1938.
4. Hopkins, A. D. Economic investigations of the Scolytid bark and timber beetles of North America. U.S. Dept. Agr. Program of Work, 1917, p. 353. 1916.
5. Painter, Reginald H. The food of insects and its relation to resistance of plants to insect attack. Amer. Naturalist, 70 : 547-566. 1936.
6. Pickett, A. D. Studies on the Genus *Rhagoletis* (Trypetidae) with special reference to *Rhagoletis pomonella* (Walsh). Can. Journ. Res. D, 15 : 53-75. 1937.
7. Thorpe, W. H. and F. G. W. Jones. Proc. Royal Soc. London, Ser. B, 124 : 56-81. 1937.
8. Wiesmann, R. Das Wirtspflanzenproblem der Kirschfliege, *Rhagoletis cerasi* L. Landu Jb. Schweiz 51 Heft 9, pp. 1031-44. Bern. 1937. (*See* Rev. Appl. Ent. 26 : 156. 1938.)

THE LIFE HISTORY OF THE PEACH BORER, *SYNANTHEDON EXITIOSA* SAY, IN ONTARIO[1]

THOMAS ARMSTRONG[2]

Dominion Entomological Laboratory, Vineland Station, Ontario

[Received for publication December 27, 1939]

INTRODUCTION

Recently the peach borer, *Synanthedon exitiosa* Say, has become increasingly troublesome throughout the peach growing areas of the Niagara Peninsula and western Ontario. Nurserymen have complained of this pest attacking young trees in the nursery rows, and the growers have feared the loss of their young trees due to the insect's ravages. A study of the bionomics and control, incepted in 1935, was continued for the past four seasons at Vineland Station and Grimsby. The notes which follow are the results of this investigation.

REVIEW OF LITERATURE

This native insect is a recognized pest in the United States, Canada and South America (Argentina). In the United States the species is prevalent in all peach growing areas east of the Rockies, and although present in the Western States it is never of much importance in that region. In Canada the insect has been mentioned in the entomological literature for many years. In 1871 and 1872, Saunders (10), in two short papers in the *Canadian Entomologist*, described the larva of the peach borer, and suggested a means of control in a paper titled "Hints to Fruit Growers". Reed (7), in 1872, gave an account of the insect, writing entirely of the work done in the United States by Fitch, Harris and others. Lochhead (4), in 1902 wrote of peach tree borers being very numerous in the Niagara district, many young trees of that year's planting being injured. Treherne (11) in 1912 stated that 80% of the 4-year old peach trees were attacked in one orchard and that the borer was attracting the attention of progressive fruit growers. He also mentioned that the first males emerged on July 12 and the first females on July 14 in the Niagara district. Caesar (3) in 1913 and 1915 mentioned an infestation of peach borers in the new peach districts of Elgin and Norfolk counties. According to Ross (8) the insect was abundant in the Niagara district in 1921 and 1922, and was very injurious in southwestern Ontario orchards in 1927. From 1933 to 1938 it was again more prevalent than usual. In British Columbia, Lyne (5)* in 1913 wrote of the peach borer as one of the most injurious insects attacking the peach and other stone fruits, and Brittain (1), the following year, wrote of *S. exitiosa** as a serious enemy of the peach in the southern Okanagan. In 1923 Ruhman (9) stated that the peach borer* caused considerable losses in peach and plum orchards in British Columbia.

[1] Contribution from the Division of Entomology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Assistant Entomologist.

* Possibly *Synanthedon opalescens* Hy. Edw.

LIFE HISTORY

The Egg

The eggs of the peach borer (Plate I, 7) are laid singly or in groups, each egg being glued to the laying surface by an exudation of a gummy nature which apparently dries rapidly. The shape of the egg when viewed from above is ellipsoidal, regular in outline, with a slightly depressed area in the centre. In colour it is brown, and the surface possesses a network of lines or veins which are more distinct at the end of the egg from which the young larva emerges. The average length of 25 eggs was 0.646 mm., and the width 0.410 mm.

In the orchard eggs have been found on the ground and on the trunk and foliage of the trees. Females have been seen to lay on soil clods 7 inches from the nearest point of a tree. In cone cages around the tree trunks the moths laid on every available object, including the cloth and screen, weeds, trash, soil, trunk and foliage.

Incubation Period

Eggs took from 9 to 25 days in which to hatch, depending on the prevailing temperatures during the period. The average length of the incubation period was in the neighbourhood of 12 days. The data are summarized in Table 1.

TABLE 1.—INCUBATION PERIOD

Year	Number of eggs	Incubation period, days		
		Maximum	Minimum	Average
1935	15,964	24	9	12.1
1936	23,398	22	11	12.8
1937	14,550	25	11	11.9
1938	35,955	25	9	11.1

The temperature relationship is illustrated in the accompanying graph, the curve being based on the 1935 records.

The Larva at Hatching Time

The young larva is present within the egg, lying in a U-shaped position, for at least two days before actually biting through the chorion. At hatching time the caterpillar measures on the average 1.65 mm. in length. When about to leave the egg the insect tears away the thin shell at the point where the embryo head rested, making a jagged opening sufficiently large for it to crawl out. The pieces of the chorion bitten off by the mandibles are clustered around the opening. For the most part it would appear that hatching occurs at night, for very rarely indeed were hatching operations observed during the day. When part of a lot of eggs of the same age hatched during the night, the rest of the eggs did not hatch until the following evening.

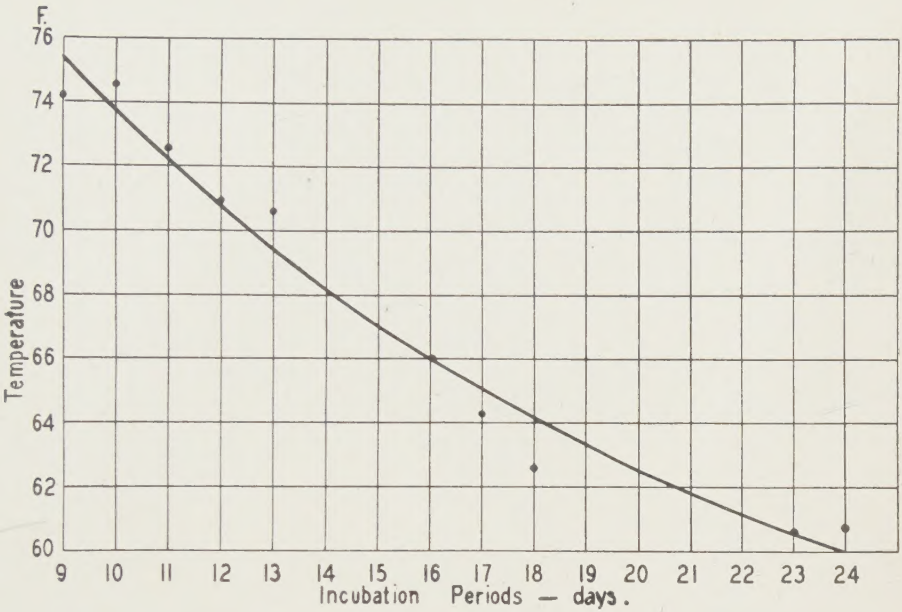

FIGURE 1. The relation of temperature to the length of the incubation period. 1935 records.

Notes on the behaviour of newly hatched larvae, as observed in the insectary in Petri dishes, showed that they always crawled downwards and away from the light beneath the shelter of layers of blotting paper. Such reactions in the orchard would lead them to their normal point of entry at or very near the junction of the soil and trunk.

Time of Hatching

In 1937, the first newly hatched peach borer larvae appeared on July 31, and eggs continued to hatch until the end of September. The time and rate of hatching during the seasons of 1936, 1937, and 1938 are summarized in Table 2.

TABLE 2.—TIME OF HATCHING

	1936	1937	1938
Hatching commenced	Aug. 2	July 31	July 27
10% of eggs had hatched by	Aug. 8	Aug. 6	July 30
25% of eggs had hatched by	Aug. 14	Aug. 10	Aug. 4
50% of eggs had hatched by	Aug. 20	Aug. 22	Aug. 13
75% of eggs had hatched by	Sept. 3	Sept. 2	Aug. 21
90% of eggs had hatched by	Sept. 9	Sept. 7	Aug. 29
91% of eggs had hatched by	Sept. 15	—	—
96% of eggs had hatched by	—	—	Sept. 15
98% of eggs had hatched by	—	Sept. 15	—
99% of eggs had hatched by	Sept. 30	—	—
100% of eggs had hatched by	Oct. 10	Oct. 1	Sept. 29
Number of eggs recorded	23,398	14,550	35,951

Growth and Feeding

The evidence of entry of the young larva is a small mound of castings on the trunk, usually close to the ground surface. These castings are heaped around the small hole, and consist of tiny pieces of bark tissue not eaten by the insect but built around the cavity probably in order to help the larva to get under cover rapidly and away from the light and heat of the sun.

Feeding is carried on from this time until cold weather sets in, at which time the various sized caterpillars lie dormant in a rough cocoon on the outside of the trunk in the midst of loose jelly-like exudations, or in the feeding cavity. Overwintering caterpillars from current year's eggs removed from their hibernacula on December 9 measured from 4 to 12 mm. in length.

Activity commences once more when the warm days of spring return, and the larvae continue to feed in their old borings, or will start new ones, until in late June and throughout July they reach maturity (Plate II, 1). Some caterpillars are found in the trees during August and September, practically full grown specimens having been collected from August 12 onwards. The presence of these individuals, definitely not of the current year's brood, feeding at this late date when pupation has ended by the first week of August, was the first indication that a percentage of larvae takes two years to mature. This was eventually confirmed by the experiments described later.

Cocooning and Pupal Period

The larval cocoon (Plate I, 6) is made of small pieces of wood and earth bound together with silk and some sticky liquid, the whole making a regularly shaped brownish or sand coloured body about 22 mm. in length on the average, with some as small as 18 mm. and others as large as 25 mm. The cocoon is constructed very close to the ground surface in an upright position so that when the pupa breaks through it protrudes above the surface. Sometimes the cocoon is located in the tree boring, but most of them are found around the tree in the soil within 3 inches of the trunk. Some of the borers taking two years to complete their life cycle, feed well down in the main roots, and when mature they migrate directly to the soil surface from where they happen to be. Cocoons thus formed have been collected as far as 14 inches from the trunk of the tree.

The soil around a group of injured trees was examined regularly for cocoons throughout the season and in this way it was possible to recover the borers shortly after they had matured. In most cases the cocoons were fully formed but quite often they were collected just as the larvae were in the process of constructing their shelters. This material was placed in glass soil tubes in the insectary and the combined cocooning-pupal period recorded, no effort being made to determine the duration of the pupal stage alone. The period varied from 18 to 43 days, the average being in the neighbourhood of 28 days as shown in Table 3.

TABLE 3.—COCOONING-PUPAL PERIOD

Year	Number of cocoons	Cocooning-pupal period, days		
		Maximum	Minimum	Average
1935	15	41	19	27.5
1936	89	43	18	29.1
1937	67	39	18	28.2

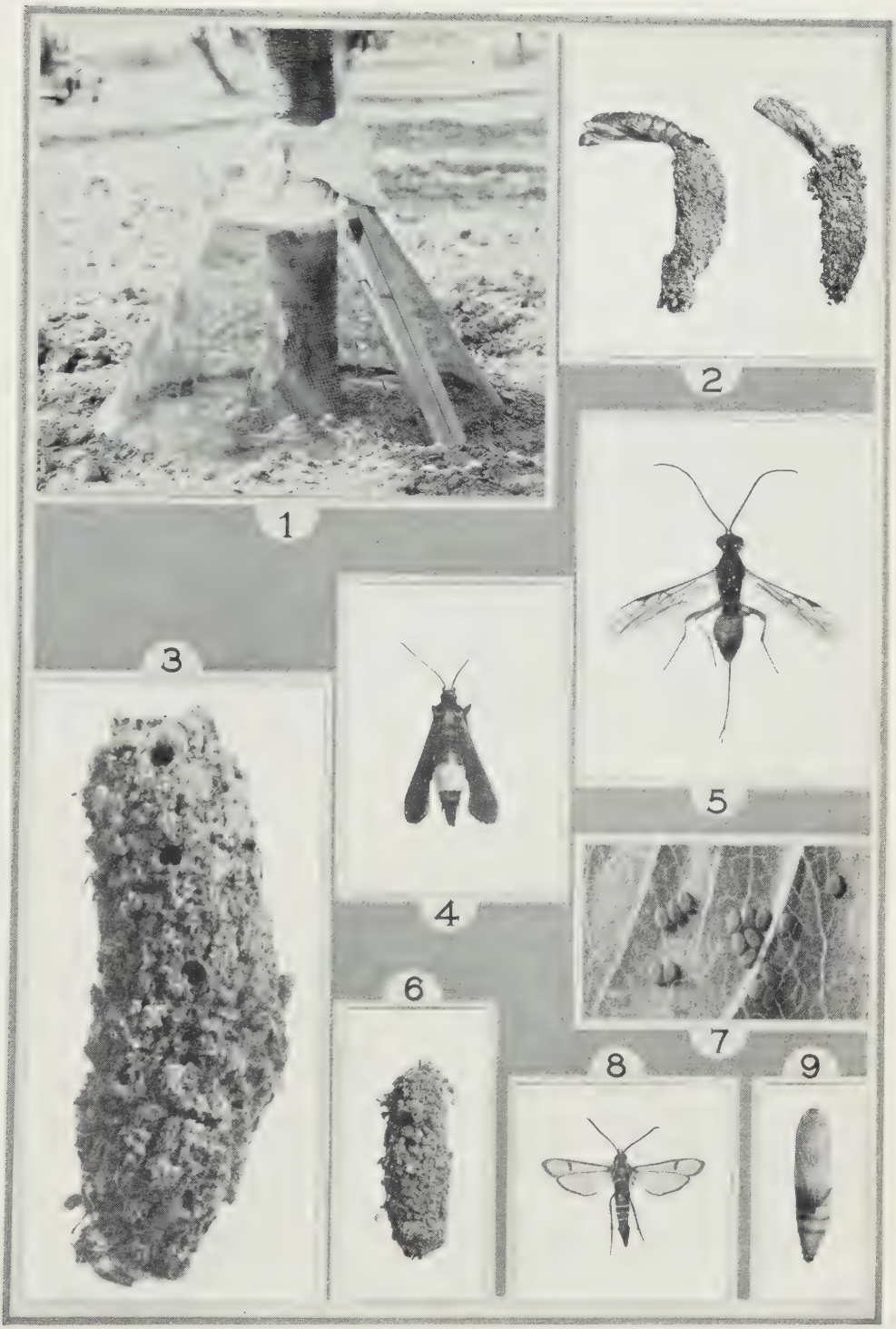

PLATE I. 1. Cone-shaped wire screen cage used for emergence records. 2. Cocoons with empty pupal cases protruding. 3. Cocoon of peach borer showing parasite exit holes; ×3.5. 4. The adult female. 5. Adult parasite, *Microbracon sanninoideae;* ×4.3. 6. The cocoon. 7. The eggs. ×3.5. 8. The adult male, wings spread. 9. The pupa.

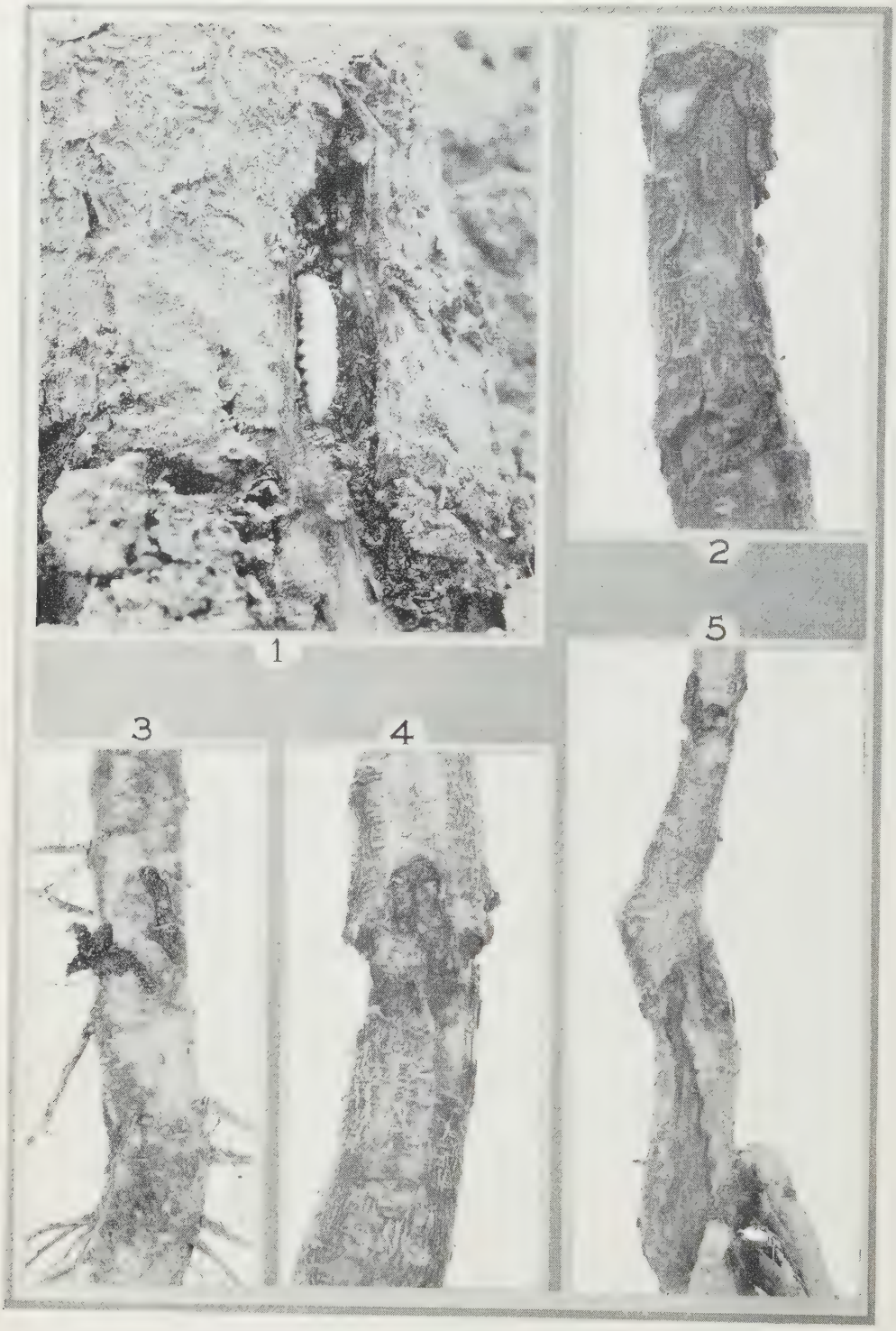

PLATE II. 1. Boring into peach tree below ground level (soil removed) showing the mature caterpillar. 2. Injury which caused the death of the young tree. 3. Injury to nursery stock by fall feeding of the borers. 4. Young tree girdled by the borer. The tree has made an effort to callous over the wound. 5. Small tree showing two feeding areas; one at the surface, the other well down in the tap root.

When the pupa (Plate I, 9) reaches maturity it forces its way out of the cocoon through a slit at the head end closest to the soil surface (Plate I, 2). As a rule it wriggles about half way out, until the body is sticking through the soil. The pupal skin splits in front and along the dorsum and the moth rapidly emerges, leaving the cast skin in position. On warm mornings, between 7 and 9 A.M., when most moths appear, the process of emergence takes but a few minutes, but cooler periods extend the time considerably.

The Adult

The peach borer moth belongs to the clearwing family Aegeriidae, and both the male and female are beautiful and attractive specimens. The male, averaging about 26 mm. in wing expanse, is somewhat smaller than the female, the latter usually spreading to about 32 mm. The two sexes are quite different in appearance. The male (Plate I, 8) is covered with dark steel blue scales with narrow yellow bands running across the abdomen. Yellowish tufts of scales are to be found on the vertex, the labial palpi, and along the dorso-caudal margin of the head, the sides and caudal margins of the thorax, and at the joints of the legs. The wings are transparent except for bands of blue and yellow scales on the margins. The abdomen is slender with a prominent triangular tuft of scales tipped with white at the caudal end.

The females (Plate I, 4) are much more conspicuously marked, dark blue in colour with a velvet sheen, and with the fourth and fifth abdominal segments, sometimes only the fourth, covered with orange coloured scales to form a deep orange band about the body. The fore wings are completely scaled, the hind wings largely transparent. The female is much more robust than the male, with a stouter abdomen.

Time of Emergence

At Vineland Station moths commence to appear in the orchards during the second week of July, and are present until around the middle of September, although emergence usually draws to a close during the first week of September. Emergence is at its height during the week commencing July 29, as a glance at the chart will show. The rate of emergence in summary form is presented in Table 4.

TABLE 4.—RATE OF EMERGENCE

	1935	1936	1937	1938
First moth emerged	July 12	July 17	July 13	July 11
10% emergence completed	July 22	July 26	July 22	July 17
25% emergence completed	July 25	July 31	July 28	July 25
50% emergence completed	Aug. 1	Aug. 7	Aug. 3	July 30
75% emergence completed	Aug. 10	Aug. 18	Aug. 12	Aug. 8
90% emergence completed	Aug. 13	Aug. 24	Aug. 19	Aug. 13
Emergence completed	Aug. 26	Sept. 9	Sept. 2	Sept. 12
Number of moths observed	109	239	191	257

During the four years 1935 to 1938 inclusive, out of a total of 769 moths, 326, or 40.9% emerged during July; 460, or 57.8% during August; and but 10, or 1.3% in September.

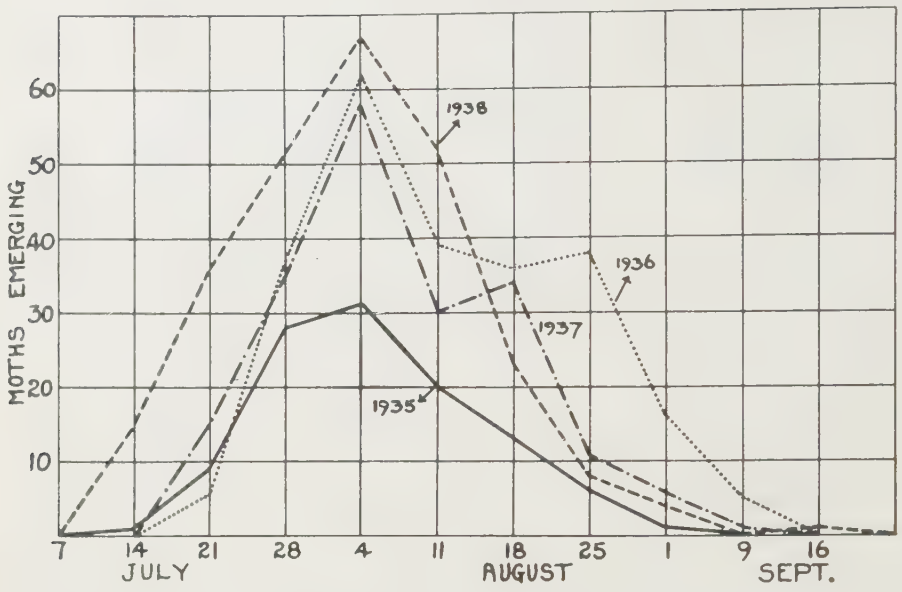

FIGURE 2. Time of emergence of peach borer moths at Vineland Station during the four years 1935 to 1938 inclusive.

Copulation

As a rule moths copulate during the morning of the day they emerge from the pupae. If the weather is cool (below 70° F.) the males do not fly, and the females are forced to wait one, two or even three days before being fertilized. The male is apparently attracted by some odour emanating from the female. The former comes up very rapidly against the wind and while still in flight stabs at the female's elevated abdomen with its claspers. This may be repeated several times before contact is made, but when successful the male turns around and rests quietly with the head pointing away from the female. In 1935, 22 females were observed to copulate for periods varying from 65 to 135 minutes, the average being 92 minutes. During 1936 the period varied from 55 to 180 minutes with the average for 28 pairs being 96.6 minutes.

Oviposition

The female commences to deposit eggs in large numbers soon after copulation has been completed, sometimes only a few minutes elapsing when high temperatures prevail. One female under observation in 1936 laid 47 eggs in the first hour after copulation, while another deposited 287 eggs in a 3-hour period. As a rule the female will lay a large number of eggs during the first day of her life, and will continue ovipositing for a period averaging four days. During the four years the oviposition period of individual females under observation varied from one to 16 days.

The rate of oviposition is extremely fast, and on a warm sunny day hundreds of eggs will be deposited by a female in a few hours. For example, one moth laid 378 eggs in $5\frac{1}{2}$ hours, while other records indicate totals of

400 to 700 eggs being deposited in a single day. The greatest number of eggs laid by a single female during its life was 962 when unfed, and 1,278 when fed a sugar-water solution. The average for 113 moths was 478, when no food was supplied.

TABLE 5.—OVIPOSITION DATA

	1935	1936	1937
Number of females observed	30	53	30
Total eggs deposited	15,906	23,541	14,549
Maximum number of eggs per female	962	951	771
Average number of eggs per female	530	444	485
Maximum oviposition period per female, days	7	12	7
Minimum oviposition period per female, days	2	1	2
Average oviposition period per female, days	4.3	3.6	4.0

During the season of 1938 female moths used in the oviposition experiments were fed once a day with a weak cane sugar solution. Fifty-five individuals were treated in this way, and the results secured are presented in Table 6. By feeding, the average number of eggs laid per female was increased from 478 to 653, while the length of life of the female was increased from 6.2 to 8.7 days.

TABLE 6—EFFECT OF FEEDING ON OVIPOSITION

	1938
Number of females observed	55
Total eggs deposited	35,955
Maximum number of eggs per female	1,278
Average number of eggs per female	653
Maximum oviposition period, days	16
Average oviposition period, days	6.6

Attracting Power of Female

A newly emerged peach borer female was placed in an electrocuting trap and the whole put in an apple tree situated approximately one-third of a mile from the nearest peach orchard. One hour later 2 males came to the trap and were electrocuted, and on subsequent days a total of 10 more males were attracted. This unmated female lived for 10 days, but did not lure any males for the last three days of her life. A repetition of the above experiment using 3 females in the trap was carried out the following season resulting in the capture of 10 males, 4 of which were caught during the first day.

Length of Life of Moths

Under insectary conditions the average length of life of 111 unfed female moths, all of which copulated and deposited eggs, was 6.2 days, the maximum life being 16 days and the minimum 2 days. Males lived a little longer than the females, their span of life varying from 5 to 12 days with an average of 8. Unmated females were quite long-lived, for the four records secured indicate periods of 10, 13, 14, and 18 days, or an average of 13.8 days, over twice as long as that of mated females.

Evidence of a Two-Year Life Cycle

During the 1937 season 12 uninjured 5-year old peach trees were infested with borers by allowing moths confined in cone cages to deposit their full complement of eggs around the base of the trees. Three more trees were provided with peach borer eggs placed at the base of the trunk after punching holes in the bark to allow the resulting larvae to make entrance as easily as possible. The trunks of these trees were left caged all through the 1937–8 and 1938–9 winters to prevent predators from destroying the borer population.

In order to prevent contamination during the period of moth flight in 1938, the trees were not only provided with a wire screen (16 mesh) cage, but around this cage a factory cotton cover was placed, fastened closely around the trunk 2 feet from the ground and plunged beneath the surface of the soil around the tree at a distance of 8 to 10 inches from the trunk.

During the 1938 season a total of 31 moths emerged from the 15 trees, and in the following season 49 moths matured from the same trees; thus 39% of them took one year and 61% two years to complete their life cycle.

During the three years of collecting in peach orchards at Vineland Station the last dates on which cocoons were found in the soil or feeding cavities were July 29 in 1935, August 4 in 1936, and August 4 in 1937. In 1936 and 1937 well developed larvae were still to be found in the borings after August 4, and they were of such a size as to eliminate any idea that they had developed from eggs laid but a few weeks earlier. Judging from the results secured from the experiment described above those larvae which do not pupate during the first year winter over for the second time and complete their life cycle in two years.

An Estimation of Mortality and Survival

Some idea as to the high natural mortality which must exist during the immature stages of the peach borer is indicated by the following experiment.

Thirty-one females were placed in cone cages around the bases of 12 trees and allowed to deposit their full complement of eggs. From data on oviposition secured from insectary rearing it was estimated that approximately 500 eggs per female, or a total of 15,500, were deposited. During the next two years 66 moths emerged from these trees, or one moth from every 235 eggs. This represents a mortality of 99.57%, most of which occurs in the larval stage soon after hatching and before establishment in the tree takes place.

Injury (Plate II)

The newly hatched larvae enter the tree by boring into the bark of the trunk just at or slightly above or below the ground level; they will also enter old wounds. Feeding is carried on in irregular tunnels within the bark or outer wood of the trunk and main roots below the ground surface, and is accompanied by the copious production of a viscous liquid which solidifies into a soft gummy mass on exposure to the air. In this gum is usually embedded the frass and castings from the borers themselves. In some instances the fall feeding of the caterpillars is carried on in quite superficial borings on the outer areas of the bark, but the spring attack is more deep-seated, with the larvae boring well into the wood.

A bearing peach tree of some considerable age, 8 years or more, is able to withstand the ravages of a number of borers without any noticeable effect on the tree or crop. For instance in one orchard of about 8 years of age 20 of the trees yielded a total of 116 borers, an average of 6 per tree, with 4 of the trees supporting 10, 15, 15, and 16 caterpillars each, yet all but one of these trees survived and bore fruit in quantity. In 1938, 25 trees yielded 178 borers, and from one tree 47 mature insects were collected. Needless to say the tree which provided food for so many insects was killed. Young trees, under 3 years old, frequently die when attacked by borers, and especially is this true of newly planted trees. One borer feeding in a young tree has been observed to girdle it completely, cutting off the food supply.

Parasites

In the Niagara district two species of parasites have been reared from peach borer cocoons. These have been identified by G. S. Walley* as *Microbracon sanninoideae* Gahan (Plate I, 5) and *Phaeogenes ater* Cress. *M. sanninoideae* emerged from the cocoons in July, as many as 16 adults maturing from a single cocoon. Three individuals of *P. ater*, each from a separate borer, were reared from material collected at Stoney Creek, the adults appearing in August.

Parasitism of the peach borer by these two insects together amounted to 2.5% during the 1937 season. No parasites were secured in 1935, 1936 and 1938. These records would indicate that parasitism is of minor importance in checking the increase of the insect.

* Division of Entomology, Ottawa.

REFERENCES

1. Brittain, W. H. Report from the Okanagan district: insect pests of the year in the Okanagan. Proc. Ent. Soc. B.C. No. 4, N.S. p. 15. Jan. 1914.
2. Becker, G. G. Notes on the peach-tree borer *Sanninoidea exitiosa*. Jour. Econ. Ent. 10 : 49-59. 1917.
3. Caesar, L. Insects of the season in Ontario. 44th Ann. Rept. Ent. Soc. Ont. p. 52. 1913. Insects of the season in Ontario. 46th Ann. Rept. Ent. Soc. Ont. p. 30. 1915.
4. Lochhead, W. The insects of the season. 33rd Ann. Rept. Ent. Soc. Ont. p. 67. 1902.
5. Lochhead, W. Injurious insects of the season. 35th Ann. Rept. Ent. Soc. Ont. pp. 28-29. 1904.
6. Lochhead, W. Injurious insects of 1905 in Ontario. 36th Ann. Rept. Ent. Soc. Ont. p. 134. 1905.
7. Lyne, W. H. Two injurious insects of economic importance attacking peach, apricot and plum trees. Proc. Ent. Soc. B.C., No. 3, N.S. pp. 34-35. 1913.
8. Peterson, A. The peach tree borer in New Jersey. N.J. Agr. Expt. Sta. Bull. 391. 1923.
9. Reed, E. B. Insects affecting the peach. Ann. Rept. Ent. Soc. Ont. pp. 44-47. 1872.
10. Ross, W. A. and L. Caesar. Insects of the season in Ontario. 51st Ann. Rept. Ent. Soc. Ont. p. 35. 1920.
11. Ross, W. A. and L. Caesar. Insects of the season in Ontario. 52nd Ann. Rept. Ent. Soc. Ont. p. 45. 1921.
12. Ross, W. A. and L. Caesar. Insects of the season 1926 in Ontario. 58th Ann. Rept. Ent. Soc. Ont. p. 17. 1927.
13. Ruhman, M. H. Report of assistant entomologist, Vernon, B.C. 18th Ann. Rept. Dept. of Agr. B.C. p. 45. 1923.
14. Saunders, W. On the larva of the peach borer. Can. Ent. Vol. 3 : 22-23. 1871. The peach borer. Can. Ent. 4 : 133. 1872.
15. Treherne, R. C. Reports on insects of the year. Niagara District. 42nd Ann. Rept. Ent. Soc. Ont. p. 23. 1911.

ADAPTATION OF THE "PICRIC-ACID TEST" METHOD FOR SELECTING HCN-FREE LINES IN SUDAN GRASS[1]

F. S. Nowosad[2] and R. M. MacVicar[3]

Experimental Farms Service, Ottawa, Ontario.

[Received for publication February 29, 1940]

The possibility that high concentrations of hydrocyanic acid (HCN) in Sudan grass, alone or in association with other compounds, may have harmful effects on the grazing animal, prompts efforts to select lines which are relatively free of this substance. A review of the literature indicates that while there are several methods, as outlined by various workers, which give a measure of the quantities of HCN present in Sudan grass herbage, no quick and practical method has been evolved for the use of the plant breeder. The well established methods which are quantitative in nature all require a considerable amount of time and are impracticable for the individual examination of plants in a breeding nursery.

Boyd et al. (1) showed that plants under examination for HCN should be in the same stage of development and grown under very similar conditions in order that the resulting data may be comparable. However, it is impossible to examine rapidly large numbers of individual plants by quantitative methods such as outlined by these workers, not only because of the time and labour involved, but because of the fact that such tests require the use of fairly large quantities of plant material. Furthermore a repetition or duplication of such a test would quickly use up the bulk of the material from the plant under consideration, and would render it useless for the study of other plant characters as well as the propagation of that plant for future work. In the search for a suitable method that could be used in the Sudan grass breeding program at Ottawa, attention was directed to the work which has been done on the determination of hydrocyanic acid in white clover.

The occurrence of HCN in white clover has been investigated by Pethybridge (4) who used the "picric-acid test" for detecting the evolution of HCN from the seedlings. Sampson (5) used the same technique as Pethybridge, and later Foy and Hyde (2), by slightly modifying the method, used the test on a large number of white clover lines. At the present time the New Zealand Department of Agriculture is guided to a considerable extent in its certification of white clover strains by the hydrocyanic acid reaction as determined by the "picric-acid test".

The "picric-acid test" as described in the following paragraphs has been adapted so that it is now regularly used in examining for HCN content large numbers of individual plants in our Sudan grass breeding nursery at the Central Experimental Farm in Ottawa. This test has the advantage of not only providing a measure of HCN content, but at the same time permits normal development of the plants so that the usual studies on plant characters can be made. Furthermore, it permits of the classification and selection of plants early in the growing season.

[1] Contribution from the Forage Plants Division, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Ontario.
[2] Assistant, (Hay, Pasture, and Nutritional Studies).
[3] Assistant, (Grass Breeding).

METHOD

The method is based on the evolution of hydrocyanic acid and the reaction of this acid when it comes in contact with filter paper treated with an alkaline picrate solution.

Preparation of Test Paper

The paper is prepared by cutting sheets of filter paper into long strips 1 cm. in width and dipping these strips into an alkaline picrate solution. The solution is prepared by dissolving 5 grams of picric acid and 50 grams of anhydrous sodium carbonate in 1000 cc. of distilled water. After the strips of paper have been dipped in the solution they are hung up to dry in a room free from chemical or other fumes. Before the strips are *absolutely* dry they are gathered up and placed in a large dessicator containing water in the bottom. They are then ready for use as required.

Test Procedure

Martin, et al. (3) showed that the HCN content of sorghum leaves was 3 to 25 times that of the corresponding stalk, but that it was the same in any one of the first four leaves from the bottom of the plant. It was therefore considered justifiable to choose any one of the lowest 4 leaves of Sudan grass and to assume that the remaining 3 leaves would provide comparable reserve material.

As the result of numerous trials as to the method of sampling and size of samples, and their subsequent treatment, the following technique is now practised.

In order to reduce the loss of moisture and of HCN to a minimum, it is necessary to have as little delay as possible from the time the sample is taken until the full operation has been completed. A great deal of time will be saved by having all the necessary equipment and means of identification ready before the samples are taken.

The third leaf from the bottom of the main stem of a plant is cut off close to the sheath and placed in a small paper bag with the necessary identification mark ascribed to it. When a limited number of samples have been collected they are immediately taken to the laboratory.

In the laboratory the entire leaf is immediately cut up with a pair of scissors into $\frac{1}{2}$-inch cross-sections, and the material thoroughly mixed. A sample of 0.5 grams of the material is then weighed out on an analytical balance and placed in a clean small test tube (10 cm. $\times$ 12 mm., or 12 cc. approximate capacity). A small short stemmed aluminum funnel is very useful for transferring the material from the balance to the test tubes. The material is forced to the bottom of the test tube by means of a glass rod, and 3 drops of sulphur-free toluene are added to kill the tissues and prevent decay. A strip of picric acid paper is then suspended in each tube in such a way that it is within $\frac{1}{4}$ inch but not touching the material. The paper is held in place by the rubber stopper with which the tube is sealed. The test tube, properly labelled is then placed in an incubator for 24 hours at a temperature of 30° C.

Under some circumstances it may be advisable to run the test in duplicate. It was found, however, that for the preliminary test single observations were sufficient.

LIBRARY
PURDUE UNIVERSITY
AGRICULTURAL EXPERIMENT

Considerable attention has been devoted to the problem of sampling. The weighing of the material is a painstaking operation which requires a considerable amount of time and precision. For this reason the possibility of sampling by leaf area is being investigated. As yet no suitable technique for sampling in this manner has been devised, having in mind that accuracy comparable to that obtained by weighing is desirable.

Classification of Results

It has been found possible to classify the plants subjected to this test in 3 different ways, any one of which may be chosen depending upon the degree of exactness required.

I. After incubation for 24 hours it is possible to classify the tubes into groups on the basis of the intensity of the reaction, as indicated by the depth of colour of the picric acid test paper. At Ottawa three classes are used, namely, light, medium and heavy. Classification in this manner permits the immediate elimination of a large number of plants which have been scored "heavy" or "medium". It will be understood that the "light" group may include plants which are free of HCN as well as some which show a slight reaction.

Methods II and III allow for a further examination of this "light" group.

II. This method involves the extraction of the colour from the test paper by placing it in a clean test tube with 10 cc. of distilled water. A coloured solution will be obtained which will be representative of the colour in the paper, by shaking the tube with a gentle tilting motion. Following this operation it is possible to classify the coloured solutions obtained into groups by visual observation.

III. This method involves taking the solutions obtained in II and comparing them on the colorimeter with appropriate standards made up for this purpose. In this way it is possible to obtain an exact quantitative reading.

In the preparation of standards it is necessary to keep in mind that the colour produced by the HCN in the Sudan grass is developed in the presence of a small amount of the alkaline picrate solution on the test paper. It is therefore necessary to make up standards containing the amount of the picrate solution that can be extracted from the strips of test paper in the absence of HCN. The paper used at Ottawa has been found by test to liberate 0.2 cc. of alkaline picrate solution when placed in 10 cc. distilled water. The constancy of this quantity is the result of having the same person responsible for the preparation of the test paper. Each new batch of paper should be checked for picric acid solution content.

By dissolving 0.241 gms. of KCN in 1000 cc. of distilled water it is possible to obtain a stock solution containing 0.1 mg. HCN per cc. Then, to a series of tubes containing 0.2 cc. of alkaline picrate solution, the following amounts of KCN solution are added:

No.	KCN solution	No.	KCN solution	No.	KCN solution
	cc.		cc.		cc.
1	0.00	4	0.20	6	0.40
2	0.05	5	0.30	7	0.50
3	0.10				

These tubes are then made up to a volume of 10 cc. with distilled water. Following this the standards are placed in a beaker of water which is then brought to boiling and maintained at that temperature for 5 minutes. Prepared in this way the standards will remain useful for about 2 weeks if properly sealed and kept in a cool place.

By the use of a colorimeter it is now possible to match the Sudan grass solutions with the standards and then calculate the amount of HCN present in them.

Efficacy of Test

By the use of the methods as outlined above it is possible to test a substantial number of plants each year. When the HCN content of the plants is the main criterion of selection, it is possible to classify, and if so desired to eliminate, a large number of plants without further consideration. In 1938 some 3000 individual plants were tested by this method. Small trials have indicated that quantitative determinations obtained by means of this test are accurate for comparative purposes and may be safely used as a basis for selecting HCN-free plants of Sudan grass.

REFERENCES

1. Boyd, F. T., O. S. Aamodt, G. Bohstedt, and E. Truog. Sudan grass management for control of cyanic poisoning. Jour. Am. Soc. Agron. 30 : 7; 569-582. 1938.

2. Foy, N. R. and E. O. C. Hyde. Investigation of the reliability of the "picric-acid test" for distinguishing strains of white clover in New Zealand. N.Z. Jour. of Agriculture, 55 : 4; 219-224. 1937.

3. Martin, J. H., J. F. Couch, and R. R. Briese. Hydrocyanic acid content of different parts of the sorghum plant. Jour. Am. Soc. Agron. 30 : 9; 725-734. 1938.

4. Pethybridge, G. H. Is it possible to distinguish the seeds of wild white clover by chemical means during a germination test? Econ. Proc. Roy. Dublin Soc. 2, 248-258. 1919.

5. Sampson, K. Cynaphoric tests with seedlings and plants of white clover. Welsh Plant Breeding Station Bull. Series H. No. 1 : 70-73. 1922.

SEED SETTING IN ALFALFA[1]

A. J. Lejeune[2] and P. J. Olson[3]

University of Manitoba, Winnipeg, Manitoba

[Received for publication March 26, 1940]

This paper is the first in a contemplated series on the general subject indicated by the title. A project was started in 1939 in which the relation of the following factors to seed setting will be studied.

1. Artificial tripping of flowers.
2. Clipping at various dates and frequencies.
3. Spacing of plants.
4. Application of lime and phosphorus to the soil.
5. Tripping flowers by insects.

The present paper deals with data gathered during 1939 under items 1 and 5.

REVIEW OF PREVIOUS WORK

The general opinion of previous workers, based on experimental data, is that tripping of flowers increases seed setting in alfalfa, and that the honey bee trips very few flowers while the bumble bee and wild leaf-cutting bee are more efficient. Piper and others (9) found that artificial tripping increased pod formation by about 25% but the number of seeds from artificially tripped flowers was .5 seed per pod less than for natural development. Carlson (4) obtained results which give a ratio of 1 : 2.5 in favour of artificial tripping. Seed pods formed from artificially tripped flowers were equal in number of seeds to those formed by naturally developed flowers. Southworth (10) obtained a ratio of 1 : 2.38 seed setting in favour of artificial tripping over natural development. Carlson (3) stated that when alfalfa flowers were artificially tripped 63.9% formed pods as against 37% pod formation with natural development. Hay (6) concluded that tripping of the alfalfa flower was not a limiting factor in seed setting. His results show an increase by artificial tripping from 5.94% to 9.48% in seed setting. Clarke and Fryer (5) found artificial tripping to increase seed setting by about 100% but, even then, less than half of the flowers had set seed.

Kirk and White (7) increased seed setting by selecting autogamous plants. The selections were made on the basis that alfalfa does not normally set seed unless tripped. Armstrong and White (1) found conclusive evidence to prove that the rupture of the stigmatic surface is essential for pollen germination and fertilization and that tripping of the flower will more than likely rupture the stigmatic surface. Brink and Cooper (2) found fertilization to take place without tripping. They indicated as high as 35% of pod formation without tripping. Piper and others (9) observed at a number of stations that leaf-cutting bees tripped flowers at the rate of about 9 out of 10. Bumble bees were inferior to leaf-cutting bees, and honey bees tripped only a few flowers. Lovell (8) in a summary of results reported to date pointed out that honey bees very rarely trip a flower; that leaf-cutting bees (*Megachile dentitarsus*) trip almost every flower visited while bumble bees trip only about one-third of the flowers visited.

[1] Contribution from the Department of Plant Science, Faculty of Agriculture, University of Manitoba, Winnipeg, Manitoba.

[2] Assistant in Plant Science.

[3] Professor of Plant Science.

THE EFFECT OF ARTIFICIAL TRIPPING

The following treatments were applied to a number of alfalfa plants, 3 plants being used for each treatment.

1. Plants caged, not tripped.
2. Plants caged, tripped by hand.
3. Plants not caged, not tripped.
4. Plants not caged, tripped by hand.

All the racemes worked with were tagged, and the number of flowers on each raceme counted. When the seed was mature, these racemes were harvested, and the number of pods per raceme and the number of seeds per pod recorded. Table 1 presents the data obtained.

TABLE 1.—EFFECT OF ARTIFICIAL TRIPPING

Treatment	No. of flowers	No. of pods formed	No. of seeds formed	% flowers forming pods	% pods forming seed	% flowers forming seed	No. of seed per pod
Caged untripped	2008	67	52	3.3	59.7	2.6	0.77
Caged tripped	3193	894	1523	28.0	85.2	47.7	1.80
Uncaged untripped	2200	162	333	7.4	87.6	15.1	2.00
Uncaged tripped	2430	794	1214	32.7	83.3	50.0	1.50

It is evident from these data that hand tripping brought about a very marked increase in the amount of seed set. In caged plants tripping increased the amount of seed more than twenty-fold (47.7 as against 2.6%). With uncaged plants the increase was more than three-fold (50 as against 15.1%). The percentage of flowers forming pods and the percentage of pods forming seed must also be taken into account, because there may be more than one seed per pod and some pods do not produce seed. With caged plants tripping increased pod formation more than eight-fold (28.0 as against 3.3%). In uncaged plants the increase was more than four-fold (32.7 as against 7.4%).

The percentage of pods forming seed was practically the same for the uncaged plants and the caged tripped plants, but on the caged untripped plants the percentage of pods forming seed was 59.7 as against 85.2, 87.6, and 83.3 for the caged tripped, uncaged untripped, and uncaged tripped plants respectively.

THE EFFECT OF TRIPPING BY BEES

Careful observations were made of honey bees and wild bees (Bombus spp.) that visited flowers in the alfalfa plots on the University grounds. These bees were followed as they visited the fields and observations made as to (1) the number of the visited flowers that were tripped, and (2) the manner in which they approached or manipulated the flowers in extracting nectar from them.

A summary of amount of tripping accomplished is shown in Table 2. Many bees were observed on several days and at several different periods during the day. In the table the total number of flowers visited by each type of bee and the number of flowers tripped is shown by days. In other words the periods of the day are not shown, and the work of each individual bee is not shown.

TABLE 2.—A COMPARISON OF THE EFFECTIVENESS OF HONEY BEES AND BUMBLE BEES IN TRIPPING ALFALFA FLOWERS

	June 20			June 22				June 23			
No. of bees	Flowers visited	Flowers tripped	% tripped	No. of bees	Flowers visited	Flowers tripped	% tripped	No. of bees	Flowers visited	Flowers tripped	% tripped
Honey bees 12	114	32	28	17	105	19	17.1	16	158	0	0
Bumble bees 5	40	39	98	6	49	44	90.0				

The most significant data are found in the column showing the percentage of the flowers visited that were tripped by the honey bees and bumble bees respectively. It is obvious that honey bees were relatively ineffective in tripping flowers, while bumble bees were close to 100% effective. On June 23 no bumble bees were observed, but on this date the honey bees visiting a total of 158 flowers did not trip a single one. Although only superficial observations were made after this date until the end of the flowering period, no honey bee was ever again found to trip a flower.

The method of approach of the bees to the flower, although of little practical interest, is of considerable academic interest. The bumble bee, practically without exception, inserted the mouth parts in front of the keel, between it and the standard. This method of approach would be expected to be most effective in accomplishing tripping. The honey bees in a great many cases approached the side of the flower and inserted the mouth parts between wing and standard, and thus failed to touch the keel at all.

A number of bumble bees were imprisoned with plants in wire cages. These did not seem to thrive under confinement and appeared to spend most of their time in an effort to get out of the cages.

SUMMARY

Tests were conducted involving *(a)* the effect of artificial tripping of individual alfalfa flowers, and *(b)* the amount of tripping done by honey bees and bumble bees that visited the flowers. Artificial tripping increased seed setting twenty fold with caged plants. Uncaged tripped plants produced more than three times as much seed as uncaged ones that were not artificially tripped. Honey bees tripped very few flowers, while bumble bees tripped nearly all flowers visited.

REFERENCES

1. Armstrong, J. M. and W. J. White. Factors influencing seed setting in alfalfa. Jour. Agric. Res., 25 : 161-179. 1935.

2. Brink, R. A. and D. C. Cooper. The mechanism of pollination in alfalfa *(Medicago sativa)*. Amer. Jour. Bot., 23 : No. 10. 1936.

3. Carlson, J. W. Seasonal behaviour of alfalfa flowers as related to seed production. Jour. Amer. Soc. Agron., 20 : 542-556. 1928.

4. Carlson, J. W. Artificial tripping of flowers in alfalfa in relation to seed production. Jour. Amer. Soc. Agron., 22 : 780-786. 1930.

5. Clarke, A. E. and J. R. Fryer. Seed setting in alfalfa. Sci. Agric., 11 : 38-43. 1930.

6. Hay, W. D. Does artificial tripping of alfalfa blossoms increase seed setting? Sci. Agric., 5 : 289-290. 1925.

7. Kirk, L. E. and W. J. White. Autogamous alfalfa. Sci. Agric., 13 : 591-593. 1933.

8. Lovell, H. Pollination of alfalfa. Amer. Bee Jour. No. 64. 1924.

9. Piper, C. V. *(et al.)*. Alfalfa seed production; pollination studies. U.S.D.A. Bulletin 75. 1914.

10. Southworth, W. Influences which tend to affect seed production in alfalfa and an attempt to raise a high seed producing strain by hybridization. Sci. Agric., 9: 1-29. 1928.

CROSS-POLLINATION OF RED CLOVER BY HONEY BEES[1]

J. M. Armstrong[2] and C. A. Jamieson[3]

Experimental Farms Service, Ottawa, Ontario.

[Received for publication March 6, 1940]

Red clover is almost completely self-sterile, and consequently a main factor in seed production is the efficacy of the cross-pollinating agencies. Cross pollination in red clover is mainly effected by species of bumble bees and by honey bees. In older cultivated areas the population of wild bees is on the decrease and this has led to corresponding decreases in red clover seed production. The honey bee does not work red clover as diligently as the bumble bee. This is believed by many observers to be due to the nectar being more difficult to obtain by the honey bee, because of its shorter proboscis. This has stimulated an attempt on the part of plant breeders to develop strains of red clover with shorter corolla tubes which would be readily worked by the honey bee. Two such strains developed by plant breeders in Bohemia were recently secured by C. B. Gooderham, Dominion Apiarist, and are under test by the Division of Forage Plants, Experimental Farms Service, Ottawa. In this paper the results of an experiment are recorded in which the relative seed production of these new strains in comparison with a standard red clover variety was studied under controlled conditions.

LITERATURE REVIEW

The fact that honey bees are capable of cross-pollinating red clover was demonstrated by Westgate and Coe (8). A large screen cage, 12 feet square and 6 feet high, was placed in a field of red clover just previous to blooming. The screen had 4 meshes to the inch which permitted honey bees to pass through but would not permit bumble bees to do so. A small colony of bees was placed in the cage and the bees soon learned to pass through the screen and worked the clover heads both outside and within the cage. The writers do not mention activity by small solitary bees although this may have been a factor. After the crop was mature several hundred heads were collected from the cage; an average of 37.2 seeds per head was obtained. In another cage with closer mesh in which bumble bees were confined, an average yield of 30.4 seeds per head was obtained. Richmond (4) studied red clover pollination by honey bees on the irrigated lands in Colorado. Here the yields are unusually high, 14 to 18 bus. per acre being secured. In these areas there is a great dearth of bumble bees and the honey bees are the main agency in pollinating the crop. In a caging experiment with honey bees Richmond obtained an average of 61.5 seeds per head as compared to 67.26 from the open field. The same worker investigated the efficacy of night pollinators but found the amount of seed produced almost negligible.

---

[1] Contribution from the Forage Plants Division and the Bee Division, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Assistant, (Alfalfa and Clover), Division of Forage Plants.

[3] Agricultural Assistant, Bee Division.

In Scandinavian countries, where considerable emphasis has been placed on red clover breeding, the question of the pollination of red clover has been investigated by several workers. Stapel (5) of Denmark observed that honey bees are more active on late-flowering than on early-flowering varieties of red clover. Experimentally he was able to increase the pollen collecting activities of colonies placed in red clover plots by feeding them sugar solutions. Sylven (7) found honey-bees visited red clover strains with slightly shorter corolla tubes more frequently than varieties normal in this respect. The studies of Valle (9) of Finland indicated that in that country as compared to bumble bees the honey bee plays only a minor role in seed formation. He observed that honey bee activity was of two kinds. Some worked as pollinating insects while other individuals sought to obtain nectar from the holes cut in the florets by *B. terristris*.

The competition of plant species for pollinating insects has been investigated by several workers. Stapel (6) noted that when the flowering season of white clover began the honey bees practically left the red clover to work on the white clover. Richmond (4) tagged red clover heads before and after alfalfa was in bloom. Red clover heads in bloom before alfalfa flowered set 62.0 seeds per head while heads in bloom at the same time as alfalfa set 67.3 seeds per head. The writer concluded that alfalfa was not a competitive plant to red clover. Many obersvers have noted that the second cutting of red clover is more frequently visited by honey bees than the first cutting and ascribe as the reason that there is scarcity of flowering plants by late August, when the second cutting is in bloom, and honey bees work red clover then due to the limited choice of flowering plants.

The relationship between the length of the bee's proboscis and the depth of the corolla tube of red clover has been investigated by several workers. Westgate and Coe (8) from measurements of first crop red clover found the corolla tube length varied from 8.5 to 11.5 mm. with an average length of 9.6 mm. Schachinger (cf. Westgate and Coe) found that corolla tubes are shorter in the second crop than in the first crop of

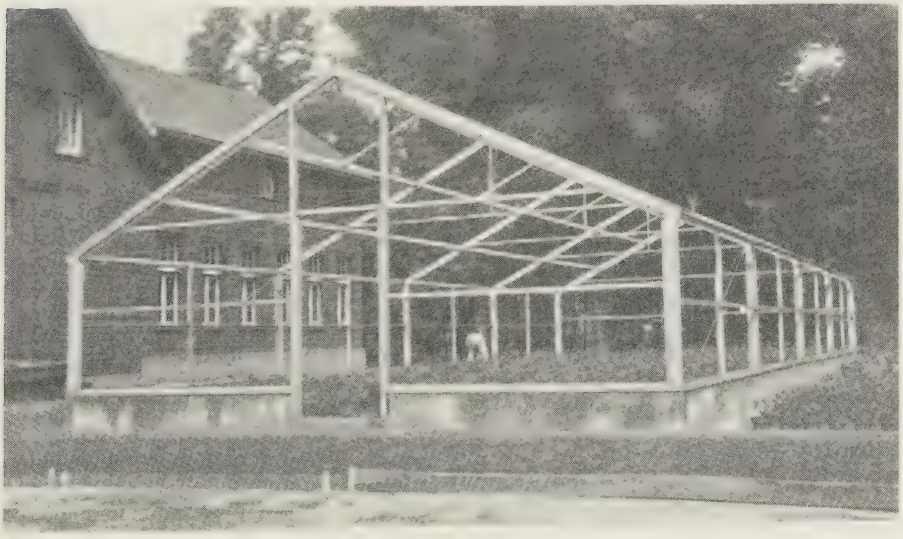

FIGURE 1. Exterior view of screenhouse after the red clover was established and before screen panels were put on.

FIGURE 2. Interior view of screenhouse showing clover in bloom with colony of honey bees on the pathway.

red clover, and for this reason smaller bees are better able to work on the second crop than on the first. Martin (1) gives the proboscis length of the bumble bee as 11 mm. and that of the Italian honey bee as 6.5 mm. Martin calculated that to 6.5 should be added 1 mm. for the distance the bee pushes her head into the top of corolla tube, and that 1 mm. should be deducted from the length of corolla due to the nectar height. The final effect would be that a honey bee could secure nectar from a corolla tube 8.5 mm. long. These estimates agree closely with those of Mikhailoff (cf. Richmond). Stapel and Erikson (6) found that the Danish bee has a slightly shorter proboscis than the Italian bee. They found by pollen analyses that 33.4% of the bees from 15 colonies of Italian bees visited red clover, which crop was visited by only 12.6% of the bees from 16 colonies of the Danish bee. They consider that the length of the bee's tongue is the determining factor. Parker (3) studied the proportions of pollen collectors, nectar collectors and dual collectors among the workers of colonies of Italian bees. He estimated that 25% specialized in collecting pollen, 58% in collecting nectar, and 17% collected both nectar and pollen on the same trip. It is known that pollen, as nitrogenous food for the young brood, is required extensively in spring and autumn, and this fact may lead to a certain amount of activity on red clover by honey bees even if the nectar secretions are not obtainable.

MATERIALS AND METHODS

The experiment consisted of growing three varieties of red clover, which differed in respect to corolla tube length, in a screen house, and subjecting them to the cross-pollinating agency of a colony of Italian honey bees. The varieties of red clover used in the experiment were:

Ottawa; An early, double-cut variety which was produced by the Division of Forage Plants, Central Experimental Farm, Ottawa. It has normal-sized, red bloom, and has been unselected for corolla tube length.

Zofka; This is an early double-cut variety originated by Dr. N. Zofka of Bohemia. It was selected with the object of securing a strain characterized by short corolla tubes.

Kellner; This strain was selected from Zofka by Mr. Kellner of Bohemia. It differs little from Zofka, being slightly more uniform for corolla tube length.

The plants were started in the greenhouse in March 1939 and transplanted to the screenhouse in May. The rows were spaced 2 feet apart and the plants 1.5 feet apart in the row. Screenhouse dimensions permitted the establishment of 142 plants of each variety. Growth conditions for the season were quite good and no difficulty from disease or insect pest was encountered. The three varieties commenced blooming at approximately the same time in early July and continued blooming over a 4-week interval.

The experience gained in the use of the screenhouse in previous years proved to be useful. The screening for the house is made of panels which can be readily put on or removed for winter storage. It was found that if the screens were put on when the plants were established in the spring the plant development was not normal. There was a tendency to stem weakness which caused bad lodging. Later the bloom was very scanty. Infestations of aphids were also bad. If the screening was deferred until the onset of the blooming period the growth was normal and the presence of lady beetles kept the plants free from aphids. Screening, when postponed in this way, had no ill effects on the flowering or the maturing of the plants. In this experiment the house was not screened until the first week in July, just previous to flowering.

FIGURE 3. Cross-sections of red clover heads. Ottawa left and Zofka right.

FIGURE 4. Corolla tubes of red clover. Florets 2 and 4 from the left have the keel and wings removed to show the staminal column. Ottawa, florets 1 and 2, had a corolla tube length of 10.6 mm. Zofka, florets 3 and 4 had a corolla tube length of 7.2 mm.

After there was a fair amount of bloom a small colony of bees was placed in the house and left there for the duration of the blooming period. The bees were restless for a few days and then adapted themselves to their confined environment. A weak sugar solution was maintained near the hive to supplement the food obtained from the clover.

During the period of bloom a typical head was taken from each plant and the mean length of the corolla tube determined from 10 measurements. This was done by taking 10 fully-opened florets from each head, placing them between two pieces of glass and measuring with calipers to the nearest tenth of a millimetre. Figure 5 shows the portion of the corolla measured. The work of the operators was facilitated by wearing head binoculars ($\times 2.5$).

When the plants were mature, 10 heads were harvested from each plant and the mean number of seeds per head for each plant determined.

RESULTS

Tables 1 to 3 summarize the data on corolla tube length and seed-setting. The difference in mean corolla tube length for the two strains Zofka and Kellner is not significant, although Kellner is slightly less variable. The mean corolla tube length of Ottawa was found to be approximately 1.5 mm. longer than that of either of the other two strains. This difference is significant as measured by the S.E. of a difference of two means. In other words selection has been effective in shortening the corolla tube a significant amount. The range of corolla tube length in

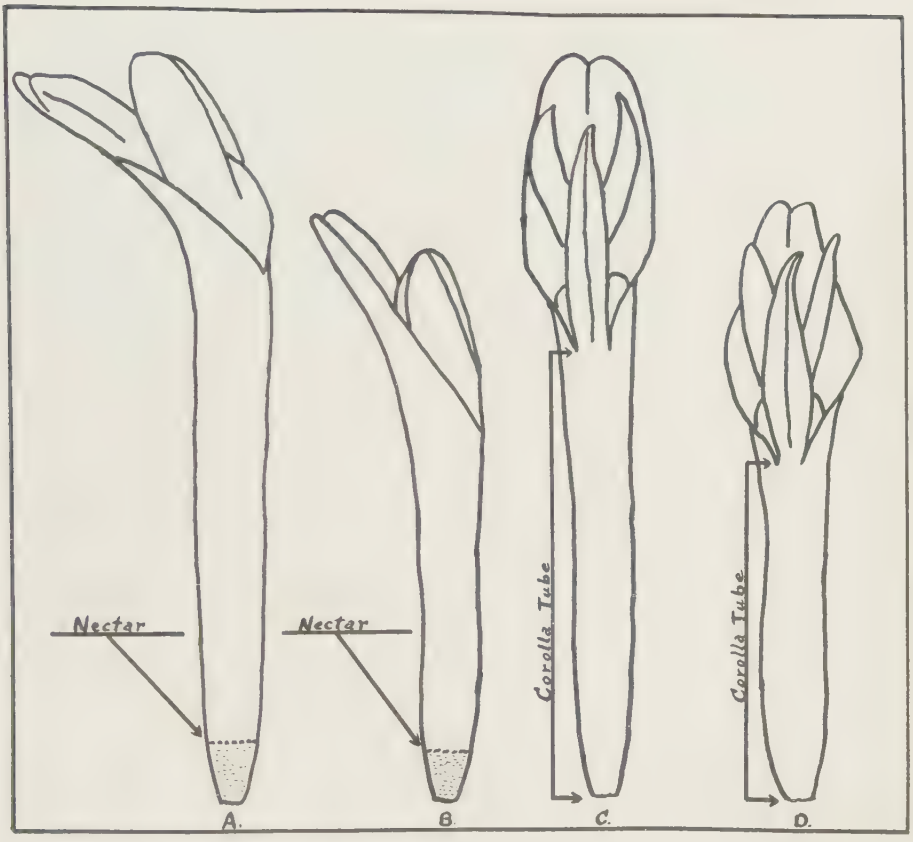

FIGURE 5. Corolla tubes of red clover. A and C from Ottawa. B and D from Zofka. A and C show the average height of nectar in the corolla tubes. C and D show the measured portion of the corolla.

Ottawa extended from 8.0 mm. to 11.8 mm. In Zofka the lengths varied from 5.5 mm. to 10.0 mm. and in Kellner from 6.2 mm. to 9.6 mm. The variation in the florets of any head seldom exceeded 0.5 mm., with 1.2 mm. as the extreme obtained. Two points might be noted in respect to corolla tube length. Firstly that in Ottawa, a variety unselected for the character, there is a variation in the population of 3.6 mm., and secondly that in the strains Zofka and Kellner, while selection has been effective in lowering the general mean, the variation is just as large as in an unselected population.

Data on the mean number of seeds per head show that Ottawa yielded an average of 39.5 seeds per head while the other varieties yielded less than half that amount. Part of this difference is due to the fact that Zofka and Kellner heads contain less florets than does Ottawa. Some plants were strikingly poor in this respect, especially in the Kellner strain, possessing heads with less than 30 florets. Part of the difference in seed production might be due to sterility factors affecting gametogenesis, although this question was not investigated. Judging from the activity of the bees there was no actual discrimination against the plants of a particular variety.

TABLE 1.—FREQUENCY DISTRIBUTION OF PLANTS OF OTTAWA RED CLOVER IN REGARD TO SEEDS PER HEAD AND COROLLA TUBE LENGTH

Median value of classes for corolla tube length (mm.)	Median value of classes for seeds per head																	Total no. of plants
	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5		
11.7						2												2
11.4				1														2
11.1		1		1		1			1									4
10.8						1	2				1							4
10.5			2	3		1	2	1				1						10
10.2			3		2	2	4	3			1							15
9.9			3	2	4	2	1	2	3	1	2				1			21
9.6	2		1	3	5	1		4	2		1							19
9.3	1	3	1	3	2	1	4	3	1	1		1						21
9.0			1	1	1		2	2	2	1		2	1					13
8.7		2	1	2	3	2	3	1	1	1								16
8.4									1									1
8.1								1		1						1		3
Total no. of plants	4	6	12	16	17	13	18	17	11	5	5	4	1	0	1	1		131

Mean number of seeds per head = 39.45 ± 1.200

Mean corolla tube length, mm. = 9.66 ± 0.064

The data was examined critically to answer the question of whether the honey bees showed a preference for plants with short corolla tubes by reason of the nectar being more available. It was thought at first that this might be determined by means of correlating corolla tube length and seeds per head for each varietal population. But it is clear that each population is divided into two classes composed of plants whose corolla tubes are so short that the bee can reach the nectar (8.5 mm. to use Martin's estimate) and of plants whose corolla tubes are so long that the nectar is not available. Any graduations within those classes would be meaningless.

Four plants occurred in the population of the Ottawa strain in which the corolla tube length was 8.5 mm. or less. These plants set seed exceptionally well, the average for the four being 61.5 which is 50% higher than

the average for the population. One plant with a corolla tube length of 8.0 mm. set 89.6 seed per head which was the highest for any plant in the screenhouse. It is perhaps significant that the plant with the shortest corolla tube in the variety under test gave the best seed-setting.

Of the Zofka plants 28.9% of the population possessed corolla tubes 8.6 mm. or more in length. The difference in the seed production in the

TABLE 2.—FREQUENCY DISTRIBUTION OF PLANTS OF ZOFKA RED CLOVER IN REGARD TO SEEDS PER HEAD AND COROLLA TUBE LENGTH

Median value of classes for corolla tube length (mm.)	Median value of classes for seeds per head																			Total no. of plants
	3.5	6.5	9.5	12.5	15.5	18.5	21.5	24.5	27.5	30.5	33.5	36.5	39.5	42.5	45.5	48.5	51.5			
9.9						1														1
9.6					1	1	1	1												4
9.3			1	1	1		1										1			5
9.0		2	1			2	2		3	1										11
8.7	2		2	1	2	2	1			2		2								14
8.4		1	2	2	5	2	5	3		1				1						22
8.1			2	1	5	4				2	1									15
7.8	2	2	2	2	2	1	3	3			1									18
7.5	1		1		1	2	1	3	1			1								11
7.2		1	3	1	1		1	1	1											9
6.9						1	1	1		1				1						5
6.6				1	1		1													3
6.3																				0
6.0											1									1
5.7				1																1
5.4								1												1
Total no. of plants	5	6	14	10	19	16	17	13	5	7	3	3	0	2	0	0	1			121

Mean number of seeds per head = 18.9 ± 0.829

Mean corolla tube length, mm. = 8.11 ± 0.073

TABLE 3.—FREQUENCY DISTRIBUTION OF PLANTS OF KELLNER RED CLOVER IN REGARD TO SEEDS PER HEAD AND COROLLA TUBE LENGTH

Median value of classes for corolla tube length (mm.)	Median value of classes for seeds per head														Total no. of plants
	3.5	6.5	9.5	12.5	15.5	18.5	21.5	24.5	27.5	30.5	33.5	36.5	39.5	42.5	
9.6			1												1
9.3									1						1
9.0	1	1	2	1	1										6
8.7	1	2	4	3	2	1	2		2						17
8.4	2	1	3	6	4	4	2	2							24
8.1	3	2	3	4	3	3	1		4				1		24
7.8	2	1	5	3	1	3	4			1			1		21
7.5	2	1	1	1		1	1							1	8
7.2	1	1	1	4				1							8
6.9	1			1	1	1	1								5
6.6	1			1											2
6.3							1								1
Total no. of plants	14	9	20	24	12	13	12	3	7	1	0	0	2	1	118

Mean number of seeds per head = 14.41 ± 0.739

Mean corolla tube length, mm. = 8.10 ± 0.055

two classes of long and short corolla tubes is very slight. The best seed producing plant in the population has a corolla tube of 9.3 mm. in length. The evidence from the Zofka population in favour of short corolla tubes is therefore not very impressive.

In the population of Kellner, 21.1% of the plants possessed corolla tubes 8.6 mm. or more in length. Here again the seed production in the two classes of plants with long and short corolla tubes is very similar. The four best plants in the population, however, possessed short corolla tubes. In this variety the distribution of plants for seed production is abnormal in that there is a higher proportion of plants that set very little seed.

DISCUSSION

The results of this experiment supply some evidence that red clover plants with short corolla tubes are superior in seed production to normal plants when subjected to the cross-pollinating agency of the honey bee.

Certain factors operate against obtaining conclusive evidence. A considerable fraction of the worker bee activity is confined to the collecting of pollen where the length of the corolla tube is immaterial. Pollen collectors might, therefore, impose a certain level of seed production on all plants in the population. Then again there are variations in the number of florets per head on the same plant and from plant to plant. The effect of the first type of variation was eliminated by taking 10 heads from each plant, but no allowance was made for the second source of variation. The height to which the nectar rises in the corolla tube is another variable factor which might affect the bee activity. This subject has never been critically examined, although different investigators have reported that the nectar height varies from 1 to 4 mm., and that nectar is secreted more abundantly on warm humid days. It is possible that since bees are more active on warm bright days, nectar might be available on plants possessing corolla tubes with a length in excess of 8.5 mm.

This experiment also confirms the findings of Westgate and Coe (8), Richmond (4) and others that honey bees can be forced to cross-pollinate red clover. There is considerable evidence to support the belief that this cross-pollination is voluntary under field conditions. The junior author examined samples of honey in 1938 which were collected in Quebec, Ontario and British Columbia. Out of 98 samples, 77 (78.6%) were found to contain red clover pollen. This indicated that there was considerable bee activity on red clover either for the purpose of collecting pollen or nectar. It has frequently been observed that honey bees are more active on the second crop of red clover than on the first. The most plausible reason is the greater scarcity of competitive flowering plants in late August when the second crop of red clover is in bloom. The evidence of Schachinger that the corolla tubes are shorter in the second crop may also be a factor. The high seed yield on the irrigated lands of Colorado reported by Richmond is apparently due to the general lack of other nectar sources for the honey bee. McLachlan (2) reports that in the U.S.S.R. in areas where red clover seed is produced the seed fields are made sufficiently large to eliminate the competition from other plants for the services of the bee colonies distributed over the field.

While it may be true that seed production in red clover may be increased by the breeding and utilization of strains with short corolla tubes, close co-operation between the bee-keeper and the seed grower would still be necessary to make sure that sufficient bee colonies were housed within easy flying distance of the seed fields. In the meantime the writers are convinced that seed production in existing strains of red clover would be greatly increased if the seed grower were fully aware that cross-pollination is just as necessary to obtaining a successful seed crop as good cultural practice in establishing and handling the crop. Since less and less dependence can be placed on the wild bee population to perform this task, colonies of honey bees must be maintained, and natural circumstances taken advantage of or artificial circumstances created so that the honey bee will act as a pollinator.

One of the difficulties of red clover breeding is that the breeder can seldom take full advantage of work done elsewhere. Strains which have proven excellent at the station of origin frequently are not adapted to other

countries differing in climatic conditions. The two varieties, Zofka and Kellner, were established in a field nursery at Ottawa in 1938. The winter of 1938–39 was not severe on legumes, but these varieties were winter-killed 40% in comparison with 5% winter-killing in Ottawa and Dollard. It is clear that further selection for winter-hardiness would be necessary before these varieties could be grown successfully under Canadian conditions. Then again varieties to be adapted to Eastern Canada should be hairy on the stems and leaves, since this character gives a certain degree of protection against leaf hopper attack. While Zofka and Kellner do show some variability as regards hairiness they are mostly composed of smooth stemmed plants. Hence to have available a strain of red clover with short corolla tubes suitable to our existing conditions further selection would be required if the European produced strain of Zofka is used. Progress in selection might be just as rapid if an adapted strain such as Ottawa were used for basic breeding material, especially since considerable variability exists in this strain in regard to the character in question.

SUMMARY

1. Results are reported on growing three varieties of red clover which differed in respect to corolla tube length in a screenhouse and subjecting them to the cross-pollinating agency of a colony of Italian honey bees.

2. The red clover varieties consisted of two strains from European sources which had been selected for short corolla tubes, and a local variety, Ottawa, which was unselected for the character.

3. The mean corolla tube length of Ottawa was found to be 9.66 ± 0.064, and that of the selected strains 8.10 ± 0.055 and 8.11 ± 0.073. Ottawa has a significantly longer corolla tube than either of the other two strains.

4. The average number of seeds per head for Ottawa was 39.45 ± 1.200 which was more than double either of the other strains.

5. Some evidence that red clover plants with short corolla tubes are superior in seed production to normal plants is indicated, but complicating factors make a thorough analysis of the problem difficult.

ACKNOWLEDGMENTS

The writers wish to thank Dr. T. M. Stevenson, Dominion Agrostologist, and Mr. C. B. Gooderham, Dominion Apiarist for helpful comments and criticisms in the course of the investigations. Thanks are also due to Mr. D. R. Gibson for valuable assistance in taking records.

REFERENCES

1. Martin, J. N. Why the high price of red clover seed? Report of the State Apiarist for Iowa. 1937.

2. McLachlan, R. G. The foraging range of bees. The Australian Beekeeper 40 : 78-81. 1938.

3. Parker, R. L. The collection and utilization of pollen by the honey bee. Cornell Univ. Agr. Exp. Sta. Memoir 98. 1926.

4. Richmond, R. G. Red clover pollination by honey bees in Colorado. Col. Agr. Coll. Exp. Sta. Bull. 391. 1932.

5. Stapel, C. Honey bees and seed production of red clover. Can honey bees be forced to pollinate red clover? Tidsskr. Planteavl. 40 : 301-313. 1935.

6. Stapel, C. and K. M. Erikson. Investigations by means of pollen analysis on the relation between honey bees (*Apis mellifica* L. and *A. mellifica* var. ligustica spinola) and red clover. Tidsskr. Planteavl. 41 : 487-529. 1936.

7. Sylven, N. Seed setting in red clover. Nordish Jordbrugsforskning 17 : 472-477. 1935.

8. Westgate, J. M. and H. S. Coe. Red clover seed production : Pollination studies. U.S.D.A. Bull. 289. 1915.

9. Valle, O. Investigations on pollination and seed formation in the red clover species. Nordisk. Jordbrugsforskning 17 : 489-497. 1935.

THE EXISTENCE OF A SEX DIFFERENCE IN THE WEIGHT OF DAY-OLD CHICKS, WITH FURTHER DATA ON THE EGG WEIGHT-CHICK WEIGHT RELATIONSHIP[1]

S. S. Munro[2] and Igor L. Kosin[3]

Experimental Farms Service, Ottawa, Ontario

[Received for publication March 1, 1940]

A number of investigators have found a high positive correlation between the size of the egg and the weight of the chick hatching from it.

Benjamin (2), Halbersleben and Mussehl (6), Jull (8), Jull and Quinn (10), Bradley (3), Upp (16), Graham (5), Kosin (13), Roberts and Hunter (15), and Penjonschkewitsch (14) all reported a high degree of association between these two factors.

Byerly (4) stated that during the initial period of development, the size of the embryo is independent of the egg size. This was corroborated by Kagiama (11) who reported that embryo growth rate rises notably after the tenth day of incubation. Penjonschkewitsch (14) found that in ducks a positive correlation between egg weight and embryo weight appears some time between the sixth and twelfth day of embryonic development. Working with bantams Kaufman (12) concluded that the small size of the bantam chick is not determined by egg size alone.

In spite of this extensive literature on the relationship between egg weight and chick weight, relatively little information is available on the possible existence of a sex difference in the weight of day-old chicks.

Both Jull (8) and Jull and Quinn (10) found that although female chicks tended to be slightly smaller at hatching time, the differences were not significant. They concluded that the weight of the chick is an unreliable indication of its sex.

Jull and Quinn (10) and Jull and Heywang (9) also reported that there was no significant difference between the sexes, when the weight of the chick was expressed as a percentage of the weight of the egg when set. They obtained these results by a simple comparison of the weights of the two sexes irrespective of parentage. On the other hand, Jourdain (7) claims that cockerels are heavier than pullets at one day of age. Jourdain's experiment, however, is not critical because the groups he compared were hatched in different seasons.

It is evident, therefore, that chick weight and egg weight are closely correlated. On the other hand, the question of the existence of a sex difference in the weights of day old chicks has not been conclusively settled. The investigation reported in this paper has been undertaken to contribute additional information on this subject.

EXPERIMENTAL MATERIAL

Both Barred Plymouth Rocks and White Leghorns were used in the experiment. Individually pedigreed eggs were weighed to the nearest tenth of a gram before setting and again on the 18th day of incubation.

[1] Contribution from the Poultry Division, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada.
[2] Agricultural Scientist.
[3] Agricultural Assistant.

Kosin (13) found that correlation between the chick weight and the 18th-day egg weight was slightly lower than the correlation between the chick weight and the weight of eggs at setting time. The differences, however, were not significant. These calculations were based on the mean weight of three chicks or more from a single dam. In the present study, all eggs were hatched individually.

On hatching, the chicks were removed from the incubator as soon as dry, pedigreed, sexed and weighed to the nearest tenth of a gram. The accuracy of sexing was checked later by autopsy. The Barred Rock chicks were hatched on three different occasions. In analyzing the data, however, each hatch was considered separately. There was only one Leghorn hatch.

RESULTS

The first step was to calculate correlation coefficients between (1) egg weight at setting time and chick weight, (2) the 18th-day egg weight and chick weight and (3) setting weight and 18th-day egg weight.

The analysis of variance and covariance was used to calculate the coefficients. This method enables one to divide the total correlation into two parts, viz., (1) that which is due to differences between the means of dams, and (2) the net correlation measuring the degree of association between individual egg and chick weights within dams. Results are summarized in Table 1.

TABLE 1.—CORRELATION COEFFICIENTS, OBTAINED BY ANALYSIS OF COVARIANCE, SHOWING THE DEGREE OF ASSOCIATION BETWEEN THE THREE VARIABLES: SETTING EGG WEIGHT, 18TH-DAY WEIGHT AND DAY-OLD CHICK WEIGHT. PENS A.C.M. ARE LEGHORNS; D.L.R. ARE BARRED ROCKS

Pen	Source of variation	Degrees of freedom	Variables correlated: Setting egg weight and chick weight	Variables correlated: 18th-day egg weight and chick weight	Variables correlated: Setting egg weight and 18th-day egg weight
A	Total	25	0.668	0.694	0.951
	Between means of dams	6	0.248	0.414	0.912
	Within dams	19	0.763	0.756	0.961
C	Total	22	0.819	0.900	0.941
	Between means of dams	3	0.989	0.964	0.979
	Within dams	19	0.619	0.789	0.918
M	Total	20	0.887	0.932	0.876
	Between means of dams	4	0.916	0.975	0.851
	Within dams	16	0.813	0.846	0.937
D	Total	23	0.802	0.662	0.842
	Between means of dams	4	0.912	0.904	0.957
	Within dams	19	0.712	0.515	0.776
L	Total	23	0.844	0.859	0.858
	Between means of dams	4	0.954	0.978	0.855
	Within dams	19	0.775	0.783	0.954
R	Total	15	0.883	0.789	0.912
	Between means of dams	2	0.795	0.745	0.980
	Within dams	13	0.920	0.809	0.910

On the whole, the correlations are high, although in pen A, the coefficient for between means of dams is surprisingly low. This apparent inconsistency has been traced to one hen, which produced chicks unusually small for the size of the eggs from which they were hatched.

In agreement with the reported data of Kosin (13) there was no appreciable difference in the degree of association between (1) the setting egg weight and chick size and (2) the 18th-day egg weight and chick size.

Finally, the last column of Table 1 shows the relationship between the weights of eggs taken on the two weighing days used in this study. The coefficients of correlation are uniformly high.

The next question to answer, and the most important one from the standpoint of this investigation, was: Is there a sex difference in the weight of day-old chicks? In order to answer this question, the progeny of each dam was considered as an independent group. The weights of male and female chicks within each such dam group constituted a series of paired observations which may be conveniently analyzed by "Student's" method. In this way the effect of differences between pens and between dams within pens is removed and the net effect of sex can be segregated and measured as such. Furthermore, the basis for comparison was the weight of chicks expressed as a percentage of egg weight, a procedure which effectively removed the influence of variability between individual eggs within dams. Summarized results are presented in Table 2.

In three out of four cases, the Barred Rock male chicks formed a significantly greater proportion of the original egg weight than did their full sisters, when their weight was expressed as a percentage of the weight of the egg. Results of a similar analysis of the Leghorn data also indicated the existence of such a sex difference.

In all five groups the male chicks were heavier relative to egg weight than were their pullet sibs. The mean percentage difference in favour of males throughout the five groups ranged from 0.6 to 1.8%.

TABLE 2.—COMPARISON OF THE MEAN PERCENTAGE CHICK WEIGHT OF EGG WEIGHT IN THE TWO SEXES. ALL COMPARISONS WERE MADE WITHIN DAMS

Breed	Hatch	No. of dams	Mean difference in per cent in favour of males	z Value for differences in per cent between male and female sibs. Odds on significance are in brackets
B. P. Rocks	Aug. 15, 1939	10	1.8	0.81 (49.3 : 1)
B. P. Rocks	Oct. 12, 1939	9	0.6	0.36 (4.62 : 1)
B. P. Rocks	Jan. 6, 1940	15	0.9	0.50 (23.3 : 1)
B. P. Rocks	Jan. 6, 1940	21	1.5	0.65 (203 : 1)
Leghorns	Oct. 12, 1939	15	1.6	0.96 (587 : 1)

TABLE 3.—COMPARISON OF THE WEIGHT OF EGGS PRODUCING MALE AND FEMALE SIBS AS WELL AS A COMPARISON OF THE BODY WEIGHT OF THESE CHICKS BY "STUDENT'S" METHOD OF ANALYSIS. ALL COMPARISONS WERE MADE WITHIN DAMS

Pen	No. of dams	Weight of eggs		Weight of chicks	
		Mean difference in grams in favour of eggs producing males.	Z value for differences between eggs producing male and female chicks. Odds in brackets	Mean difference in grams in favour of males	Z value for differences between male and female chicks. Odds in brackets
1	15	0.2	0.12 (1.80 : 1)	0.8	0.559 (31.3 : 1)
3	21	0.03	0.012	0.9	0.419 (21.5 : 1)

As was mentioned before, the comparison of chick weights on the basis of percentage chick weight of egg weight removes from the calculation the effect of variation on individual egg and chick weight. Nevertheless, it was considered advisable to extend the analysis in order to establish (1) if there was a significant difference between the weight of eggs producing male and female sib chicks, and (2) if no such difference was found to exist, to determine if male chicks were heavier than their full sisters.

Again the method of paired observations was applied to the data, and all comparisons were made within dams. Results are summarized in Table 3. The data from the Barred Rock pens 1 and 3 only were used, because of the relatively large number of chicks available from each of these two pens.

It will be seen that in neither of the two pens was there a significant difference in the weight of the eggs producing male and female sibs. Furthermore, as would be expected from the findings presented earlier in Table 2, there was a significant difference in the hatching weight of the full brother and sister chicks. In every case the male chicks were heavier. These results disagree with the already mentioned conclusions of Jull and Quinn (10) and Jull and Heywang (9).

The final phase of this investigation was concerned with determining whether the sexes differed in degree of correlation between egg weight and chick weight. The analysis of variance and covariance was used to remove the effect of the dams. The data were analysed separately for each pen and later pooled by adding the degrees of freedom and the sum of squares, thus giving pooled correlation and regression coefficients for each sex. The data are presented in Table 4.

TABLE 4.—SUMMARY OF ANALYSIS OF CO-VARIANCE, SHOWING THE RELATIONSHIP BETWEEN SETTING EGG WEIGHT AND DAY-OLD CHICK WEIGHT FOR EACH SEX

Pen	Sex	Source of variation	Degrees of freedom	Correlation coefficient	Regression of body size on egg weight in grams
1 and 3	Male	Total	117	0.868	
		Between means of dams	31	0.934	
		Within dams	86	0.585	0.507
	Female	Total	127	0.869	
		Between means of dams	32	0.918	
		Within dams	95	0.595	0.357

It is evident from the examination of Table 4, that there is no sex difference in the degree of relationship between the weight of the chicks and the setting weight of eggs. In the day-old male Barred Rock chicks the regression of body weight on egg weight was found to be 0.507 gms. as compared with the regression coefficient of 0.357 gms. in the females. However, the difference between these regression coefficients is not statistically significant.

DISCUSSION

In contrast to the earlier studies, results obtained in this investigation show that there is a sex difference in the weight of day-old male and female chicks. This disagrees with the conclusions reached by Jull and Quinn (10) and Jull and Heywang (9), who found that there was no significant sex-difference in the day-old weights. Jull (8) concluded that much larger numbers of chicks than used in his study were necessary to obtain a difference that would be significant before the eighth week of age. Ackerson and Mussehl (1) using a total of 800 chicks state there was a significant difference in the weight of male and female chicks at one week of age. No weighing was done before the seventh day.

A possible explanation of the failure of the earlier investigators to secure a significant difference at hatching time, is that in their studies the male and female chicks were compared without any regard to the influence of family differences on their weight.

The populations studied by Jull and Quinn (10) and Jull and Heywang (9) may not have been large enough to remove these differences completely.

It must be remembered that the difference between the means of body size when body weight is expressed as a percentage of egg weight ranges only from 0.6 to 1.8 in favour of the males. It can readily be appreciated, therefore, that this small difference can be easily masked, unless data are carefully analysed. Although such a small difference cannot serve as a practical method of "chick sexing", it is nevertheless of fundamental interest.

Assuming, therefore, that there is a sex difference in the weights of the day-old sibs, it should be of interest to determine how a male embryo, starting with the same amount of food material as is available to its female sib (when eggs are of equal weight), ends up by possessing a heavier body weight.

Byerley (4) concluded that the rate of growth of the chick embryo depends upon an inherent growth rate which is modified during incubation in direct proportion to the egg size. Kagiama (11) stated that sex differences in the oxidation and reduction powers of chick embryos become apparent by the 13th day of incubation, which corresponds closely to the time when the sex difference in body weight gain becomes first noticeable, the rate of gain being greater in the male embryo.

The findings presented in this paper show that unit for unit of egg weight, the day-old male chick is heavier than its female sib. This may be explained by assuming (1) that the male chick embryo draws more on the shell for its calcium supply than does the female chick, and/or (2) the male embryo is more efficient in making use of exogenous factors (atmospheric elements) for body growth.

Studies are planned in this laboratory to throw more light on these somewhat perplexing physiological interactions.

SUMMARY

(1) Data presented in this study support earlier findings that chick weight and egg weight are closely and positively correlated.

(2) While the sex of the chick is not governed by the weight of the fresh egg, there is a sex difference in the weight of day-old male and female sibs. The difference is in favour of males, ranging from 0.6 to 1.8% when body weight is expressed as a percentage of egg weight.

(3) Some theoretical considerations, following out of the findings reported in this paper, are discussed.

REFERENCES

1. Ackerson, C. W. and F. E. Mussehl. Sex differences in the normal growth rate of chicks. Jour. Agric. Res. 40 : 863-866. 1930.
2. Benjamin, E. W. A study of selection for the size, shape and color of hen's eggs. Cornell Agr. Exp. Sta. Mem. 31. 1920.
3. Bradley, R. C. The loss of weight of eggs during incubation and the factors affecting it. Unpublished thesis, Cornell University. 1926.
4. Byerly, T. C. Growth of the chick embryo in relation to its food supply. Jour. Exp. Biol. 9 : 15-45. 1932.
5. Graham, W. R. Jr. Some factors affecting the weight of egg in domestic fowl. Sci. Agric. 12 : 427-446. 1932.
6. Halbersleben, D. L. and F. E. Mussehl. Relation of egg weight to chick weight at hatching. Poultry Sci. 1 : 143-144. 1922.
7. Jourdain, W. L. Comparison of growth in sexed and in unsexed pullets. N.Z. Jour. Agric. 52 : 293-295. 1936.
8. Jull, M. A. Differential sex growth curves in Barred Plymouth Rock chicks. Sci. Agric. 4 : 58-65. 1923.
9. Jull, M. A. and Burt. W. Heywang. Yolk assimilation during the embryonic development of the chick. Poultry Sci. 9 : 393-404. 1930.
10. Jull, M. A. and J. F. Quinn. The relationship between the weight of eggs and the weight of chicks according to sex. Jour. Agric. Res. 31 : 223-226. 1925.
11. Kagiama, Sakoe. On the sex difference in the oxidation and reduction powers in the tissue. IV. On the sex differences of oxidation and reduction in the tissues of chicken embryos. (Trans. title). Jour. Biochem. (Japan), 17 : 135-146. 1933.
12. Kaufman, Laura. The origin of the differences in the body size in chickens. Archiv. für Geflügelkunde 10 : 374-377. 1936.
13. Kosin, Igor L. Relations between weight of egg and weight of chick. Unpublished thesis, University of British Columbia. 1933.
14. Penjonschkewitsch, E. E. Embryonic development of ducks and hens in relation to the weight of the eggs. Probleme der Incubation. (U.S.S.R.) 2 : 62-75. 1936.
15. Roberts, E. and J. A. Hunter. Size of Chinese and American breeds of chickens and eggs. Peking Nat. Hist. Bul. 9 : 83-92. 1934–35.
16. Upp, C. W. Egg weight, day-old chick weight and rate of growth in the S.C.R.I. Red chicks. Poultry Sci. 7 : 151-155. 1928.

HOG CARCASS STUDIES[1]

EFFECT OF EARLY RATE OF GROWTH ON LEANNESS OF CARCASS.

E. W. CRAMPTON[2]

Macdonald College, Quebec

[Received for publication December 13, 1939]

Recently reported studies (1) have indicated that the character of bacon carcasses may be related to the rates of growth of the pigs at various stages in their development. Thus rapid gains induced by liberal feeding during the early feeding period (i.e. from weaning time up to a weight of about 100 pounds) tend to produce a carcass with a large percentage of lean, while restricted gains at this time result in a relatively fatter carcass.

The studies on which these conclusions were based not only involved wide differences in growth, but rates considerably slower than are aimed at in practical pig feeding in Eastern Canada. Pigs fed for rapid early growth, for example, gained 55 pounds during the eight weeks following weaning, or at the rate of 0.9 pounds per day, while those on restricted feed gained but 25 pounds over the same period, or 0.4 pounds per day. The question is raised, therefore, as to whether under actual feeding conditions differences in early rate of gain between pigs are likely to be factors in the leanness of the carcasses eventually obtained. Inasmuch as leanness is one characteristic which contributes heavily (20% maximum) to the carcass score used in qualifying breeding sows for Advanced Registry the question is also of importance to the pig breeder.

Closely associated with this problem is the widespread belief that heavy feeding of young pigs has a tendency to result in a shortening of the carcass (first rib to aitch bone) with a resulting penalty in carcass score.

This paper is a report of a statistical study of data bearing on these questions. The data involve 247 carcasses from pigs whose individual feeding and growth records were also available and whose breeding and management were comparable.

EXPERIMENTAL

For this study data from 8 feeding tests were taken, all of which had involved individual feeding of the pigs from weaning time (at about 60 days of age) to a market weight of 200 pounds.

In all tests the pigs were full-fed, three times daily to a weight of 100 pounds and twice daily thereafter. At each feeding, the dry meal allowance was placed in the troughs and the water allowance poured over it.

[1] Contribution from the Faculty of Agriculture of McGill University, Macdonald College, P.Q., Canada. Macdonald College Journal Series No. 136.

[2] Associate Professor of Animal Nutrition.

The rations from weaning time to the 100 pound weight consisted of 85% basal feeds (various mixtures of barley, oats, corn, wheat and rice) plus 15% of a mixed protein-mineral supplement whose average composition closely approached: tankage, 50%; fish meal, 15%; linseed oilmeal, 15%; minerals, 20%. From the time the pigs reached 100 pounds to market weight the proportion of supplement was reduced to 10%.

The pigs were slaughtered at 200 pounds and their carcasses cut and measured under the plan followed for hogs from the Advanced Registry Feeding Stations.

In the statistical analyses, all constants were calculated from the "within group, within sex" variances or co-variances, thus eliminating effects of differences in average growth rates between feeding groups and any differences related to sex. The data used in this study were as follows:

Daily gain. The average daily live weight increase of the pigs from the beginning of their feeding (about 8 weeks of age) to the end of the "growing period" at a weight of 100 pounds.

Daily feed. The average daily air dry feed consumed by the pigs for the growing period (see above).

Adjusted gains. The observed daily gains adjusted by linear regression to gains expected on the average daily feed consumption of the 247 pigs.

Carcass length. The measurement in inches from the front of the first rib to the point of the aitch bone as exposed in the split carcass. This is a partial index of type of pig.

Area of loin muscle. The surface area of the cross section of the loin muscle *(longissimus dorsi)* taken between the third and fourth lumbar vertebrae. This measurement has been found to be significantly correlated with the lean-fat proportions of the pig carcass and so is used as an index of leanness.

Per cent lean. The percentage which the surface area of the lean parts of the rasher is of the total surface area of the full bacon rasher. This is another index of fat to lean in the carcass.

RESULTS

The averages and the variability of the items considered in this study are given in Table 1.

TABLE 1.—MEANS AND STANDARD DEVIATIONS OF GAIN, FEED AND CARCASS DATA

Item	Mean	Standard deviation	Coef. of variation, %
Daily gain (weaning to 100 lb.)	1.10 lb.	.14 lb.	12.7
Daily feed (weaning to 100 lb.)	3.57 lb.	.38 lb.	10.6
Gains adjusted to equal feed intake	1.10 lb.	.12 lb.	10.9
Carcass length	30.11 in.	.81 in.	2.7
Area of loin muscle	4.99 sq. in.	.61 sq. in.	12.2
Per cent lean in bacon rasher	44.11%	4.54%	10.3

For pigs of the ages and weights represented in this study, the average daily gains and feed consumptions shown in Table 1 are quite typical of well-fed bacon hogs in Eastern Canada. The variability of all of the items is normal as measured by our experience. It is believed, therefore, that the data satisfactorily represent practical hog feeding practice and typical carcasses to be expected from such practice.

The correlations between these items are given in Table 2.

TABLE 2.—SIMPLE CORRELATIONS BETWEEN DAILY GAINS, DAILY FEED, LENGTH OF SIDE, AREA OF "EYE OF LEAN" AND % LEAN IN THE BACON RASHER

—	Length of side	Area of loin muscle	Per cent lean in rasher	Average daily feed
Observed daily gain	.0385	−.0685	−.1087	.4485
Gain adjusted for equal feed intake	.1035	−.0453	−.0111	–
Length of side	–	.0654	.0949	–
Area of loin muscle	–	–	.3898	–

r needed for significance with P 0.01 and $n = 171$ is 0.19 (approx.)

As measured by simple correlation it is evident that in these hogs rate of gain was not related to length of side nor to leanness of carcass. Nor is length correlated with leanness. Gains are of course related to feed intake.

Simple correlations suffer from the fact that they measure the "over-all" relationship between two variables. This often complicates interpretation of the coefficient. In this particular problem a possible common association of length of carcass with rate of gain and with leanness must not be overlooked. Accordingly, the partial correlation between rate of gain (1) and percentage lean in the rasher (2), with length of side (3) constant, was calculated and a value for $r\,12\cdot3 = -0.0222$ obtained. It is obviously not significant.

Partial regressions indicated that carcass length (which is an index of pig type) was much more closely related to leanness than was rate of early gains in live weight. But differences in rate of gain and carcass length together appear to account for but about 1% of the variations in leanness of the carcass. ($R^2 = 0.0094$).

DISCUSSION

This study was not undertaken to prove or disprove any theories concerning the physiological development of the pig carcass. On the other hand the rather widespread belief among feeders that full feeding of young pigs is likely to lead to short, fat-type hogs at 200 pounds live weight is diametrically opposed to the idea that slow early gains, which are bound to result from restricted feeding, leads to this fat carcass. If there is any

relationship between rate of gains and carcass excellence which is of importance in everyday bacon hog production, it should be evident in a typical population of pigs in which feed intakes vary according to appetite, and gains differ between pigs in accordance with whatever factors may operate under such conditions.

The results obtained from this study are clear cut. Within the range of these data, no significant relationships were found between rate of gain in live weight and either the length of the bacon carcass produced or its leanness. Rates of gain varied sufficiently that there was more than 0.25 pounds per day difference between the slowest gaining $\frac{1}{6}$ and the fastest gaining $\frac{1}{6}$ of the pigs. Feed intakes differed by more than $\frac{3}{4}$ pounds per pig per day between these two extreme groups of the population. Nevertheless, there was no evidence that the pigs that ate least or gained least during their "growing period" had carcasses any different from the average in so far as length or leanness was concerned.

CONCLUSIONS

The practical significance of these findings will doubtless differ with different cases. It seems evident, however, that differences in rate of gain of healthy young pigs in a given herd or on a given feeding regimen cannot safely be taken as an index of probable ultimate carcass quality.

REFERENCE

1. McMeekan, C. P. Shape of the growth curve as a controlling factor in conformation and anatomical composition of the animal body—swine. Amer. Soc. An. Prod. Proc., p. 337. 1938.

BOOK REVIEWS

VEGETATIVE PROPAGATION OF TROPICAL AND SUB-TROPICAL PLANTATION CROPS. Fielden, G. St. Clair and Garner, R. J. Technical Communication 13 of the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England, 1940, pp. 99, bibl. 284, 3/6.

When in 1936 the Imperial Bureau of Fruit Production issued a technical communication dealing with the vegetative propagation of some 100 fruit varieties grown in the tropics and sub-tropics, it was not without misgivings as to the number of persons likely to be interested.

That such fears were unwarranted was quickly shown by the demand on issue. This was immediate and so considerable as to necessitate the reproduction of the publication in the following year.

The present work by the renamed Bureau, which deals, appropriately enough, with the vegetative propagation of some 55 plantation crops, should form a useful companion volume.

The help of technical experts has been invoked for adequate treatment of such major crops as rubber, coffee, cacao, etc., while the foreign literature has been thoroughly combed for details of propagation of the less familiar, but nevertheless, important crops.

One feature of the previous work which commended it also to workers in temperate regions is retained and considerably enlarged. That is the section devoted to methods used in vegetative propagation. The descriptions there are supported by simple, clear, line drawings of some 17 types of graft and 7 types of budding commonly used in vegetative propagation.

In addition tropical workers will be glad of the account and illustrated detail of the construction of loosely woven potting baskets which have been found so useful a substitute for pots in nursery work in the tropics.

For those who wish to study originals a list of references immediately follows the discussion on the propagation of each particular crop.

VEGETATIVE PROPAGATION OF TROPICAL AND SUB-TROPICAL PLANTATION CROPS. By G. St. Clair Fielden, B.A., and R. J. Garner, N.D.H., Dip. Hort. Sci. Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent. England. Price 3/6.

In 1936, having gathered its information from many scattered journals and from correspondents in different parts of the world, the Bureau issued Technical Communication No. 7 on the vegetative propagation of some 98 tropical or sub-tropical fruit species. The demand for this necessitated its re-issue in 1937.

The present compilation is a sequal and deals with the vegetative propagation of cacao, coffee, tea, rubber, cinchona and some 50 other plantation crops.

A feature of Technical Communication No. 7 was the simple line drawings of the different grafting and budding operations referred to in the text. These are reproduced in Technical Communication No. 13 together with new drawings which show the etiolation method, strap grafting, tongue-inarching, four methods of graft used in topworking and finally the method of making potting baskets which have proved so useful in tropical propagation work.

Each section concludes with a list of articles to which reference can be made for further details.

Plant Breeding Abstracts

The Director, Imperial Bureau of Plant Genetics directs attention to the reference journal "*Plant Breeding Abstracts*".

This journal contains classified abstracts of all works appearing all over the world in the fields of plant breeding and the genetics and cytology of economic plants, and also allied fields such as applied statistics and other sciences. The journal appears quarterly, four numbers per volume, and each number also contains numerous book reviews, notices of new journals, and other information in the same fields.

The subscription price of "*Plant Breeding Abstracts*" is 25/- per volume (Great Britain and the other countries of the British Commonwealth of Nations 20/-) and orders may be placed either direct with the Bureau or through any bookseller.

Lists of the other publications of the Bureau are also enclosed and we hope that this circular will be the means of establishing between your institute and the Bureau a closer co-operation which will prove of mutual value.

Quarterly 25/- per annum (subject to a reduction of 5/- per annum to subscribers within the British Commonwealth sending their subscriptions direct to the Bureau), single numbers 7/6. Back numbers of Vol. V onwards at 35/- per volume, single numbers 10/-.

Copies of "*Plant Breeding Abstracts*" printed on one side of the paper can be supplied, for the convenience of readers wishing to cut up and file the references, at an additional cost of 5/- per volume.

Technical Communications—

	s.	*d.*
Vernalization and Phasic Development of Plants	10	0
An Outline of Cytological Technique for Plant Breeders	1	6
The South American Potatoes and their Breeding Value	3	6
The action and use of Colchicine in the Production of polyploid Plants, by J. L. Fyfe	1	0
Field Trials: their lay-out and Statistical Analysis by John Wishart	2	6

Bibliographical Monographs—

	s.	*d.*
Breeding Varieties Resistant to Disease	2	0
Breeding Resistant Varieties, 1930–33 (Supplement)	2	0
Oat Breeding Bibliography	1	6
Rice Breeding Bibliography	1	6
Bibliography on Interspecific and Intergeneric Hybridization in Relation to Plant Breeding	2	0
Account of Research in Progress in the British Empire	3	6
Rye Breeding Bibliography	1	6
Bibliography on Breeding Sorghums and Millets	1	0
The Experimental Production of Haploids and Polyploids	2	6
Tobacco Breeding Bibliography	1	0
Bibliography of Baking Quality Tests, Supplement	1	6
Bibliography on Cold Resistance	1	6